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U. S. DEPARTMENT OF AGRICULTURE.

# Department Bulletins

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# THE MANUFACTURE OF COTTAGE CHEESE IN CREAMERIES AND MILK PLANTS.

By Arnold O. Dahlberg, *of the Dairy Division.*

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Cottage cheese, properly made, offers a most palatable and nutritious article of food at a relatively low price compared with the cost and nutritive value of many other foods, and the demand for it is increasing with the greater knowledge of its true value as a food. This variety of cheese may be made from skim milk, or a mixture of skim milk and buttermilk. The simple method of manufacture recommends its adoption by creameries and milk plants having skim milk or buttermilk which it is desired to dispose of to good advantage. Very little additional equipment is required, and the cost of manufacture is low, which enables the creamery to pay the patrons a good price for the skim milk.

## GOOD RAW MATERIAL ESSENTIAL.

As the quality of cottage cheese is entirely dependent upon flavor and texture, it is very important to have milk of a good, clean flavor, free from any foreign odors. The maker can control the texture of the cheese, but if the flavor is to be controlled, good raw material is necessary.

## PASTEURIZATION OF SKIM MILK IMPORTANT.

It is advisable to pasteurize the fresh skim milk just as it comes from the separator, and to begin manufacturing as soon as possible, in order to control the fermentation or souring to the best advantage. No trouble need be experienced in making a high quality of cottage cheese, possessing both the characteristic flavor and body, from properly pasteurized skim milk of good quality. Pasteurizing the milk at a temperature of 145° F. for 30 minutes in no way affects the coagu-

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lability of the milk or the handling of the curd in making cottage cheese. A higher temperature, however, should be avoided if the best results are to be obtained, because it gives a fine curd which is much harder to handle during the process of manufacture. Perhaps the greater portion of the cottage cheese used is made from raw skim milk, but the benefits to be derived from proper pasteurization are so great as to make it highly advisable to adopt that system of manufacture. Pasteurization adds but little to the cost of making and has the following important points in its favor:

1. It insures a sanitary, safe food product free from all danger of disease-producing bacteria.
2. It makes it possible to exercise a more perfect control of souring through the use of pure-culture starters, thus insuring the formation of an acid curd, giving the characteristic, mild, sour-milk flavor so much desired.

Pasteurization requires little additional work, provided suitable equipment is available. The use of a pasteurizing vat, so elevated as to allow the pasteurized milk to run into the "making vat" by gravity, gives most satisfactory results.

## EQUIPMENT REQUIRED.

Any equipment needed for making cottage cheese, in addition to that already in the creamery or milk plant, depends upon the apparatus on hand and whether the skim milk is to be pasteurized. When a pasteurizer and a channel-bottomed vat are available, very little expense is necessary. Assuming that the skim milk is to be pasteurized, the following-named apparatus will be needed:

Pasteurizer.
Channel-bottomed cheese vat.
Drain rack.
Drain cloths.
Curd knives.
Curd pail.
Vat whey strainer.

### PASTEURIZER.

The holding system of pasteurization is to be preferred. It requires a pasteurizing vat which may also be used for cooling the skim milk to the ripening temperature, after which the milk is run into the making vat. The skim milk for more than one batch of cheese may be handled in one pasteurizing vat, provided all of it does not have to be taken care of at once.

The flash method of pasteurization can be used with good results, but in order to prevent any possible effect upon the natural coagulation of the milk care must be taken to guard against the use of too high a temperature.

In case the cottage cheese is to be made from unpasteurized skim milk, the largest item of expense, which is the pasteurizer, will be eliminated.

### CHEESE VAT.

The channel-bottomed cheese vat is of the ordinary type, with a steam connection for the purpose of heating the curdled skim milk.

### DRAIN RACK.

The drain rack (fig. 1) should be made of either cypress or a good grade of white pine. A frame 3 feet 4 inches wide by 6 feet 4 inches long, outside dimensions, is made of surfaced 2 by 4 inch material, using mortised joints and allowing the ends of the longer pieces to project 3 inches. This frame is made by laying the pieces flat. On the inside edge of each side piece bore a $\frac{7}{8}$-inch hole, about 2 inches deep, 1 foot each way from the middle, and slip a half-inch galvanized pipe of the proper length into the hole when putting the frame together. The pipes support the wire screening and keep it from getting loose. Three galvanized swivel casters are fastened to each side on the bottom of the frame to allow the drain rack to be handled conveniently. Galvanized-wire screen of four meshes to the inch is nailed to the top of the frame with staples, taking care to draw it tight and let it extend a little over the middle of the frame all around. A wooden strip, wide enough to cover the edge of the galvanized screening, is nailed around the outside edge of the upper part of the frame, to hold the top part in proper position. The top part is made of $1\frac{1}{2}$ by 12 inch surfaced material with mortised and spiked corner joints, each end of the side pieces projecting 6 inches. These projections, trimmed down to the shape of a handle, make the rack more convenient.

Two drain racks of the dimensions given are large enough to hold the curd from 400 gallons of skim milk. The curd drains quickly in the drain racks, which permits them to be used repeatedly until all the cheese is made.

### DRAIN CLOTHS.

The material used for the drain cloths must be easy to wash and so strong that it will not tear during the manipulation of the curd. The drain cloths made of cheesecloth of the kind ordinarily used are unsatisfactory because they lack strength, whereas those made from a grade of even-count, round-thread, unmercerized voile are very satisfactory and easy to keep clean. A drain cloth of the latter ma-

FIG. 1.—Drain rack.

terial will outlast several of those made from ordinary cheesecloth. To make a cloth of suitable size for a drain rack 3 feet wide, 6 feet long, and 12 inches deep, it is necessary to have two pieces of 36-inch material 3 yards long, which are sewed together at the middle with a treble flat seam and the edge hemmed to prevent raveling and unnecessary wear.

### CURD KNIVES.

Two kinds of knives are used. One, which cuts the curd into horizontal layers about one-half inch thick, has metal strips or wires fastened horizontally to a frame. This knife is used by drawing it through the curd the long way of the vat. The second knife, which cuts the layers first into half-inch strips the length of the vat and then into cubes, has its strips or wires fastened vertically. The first cutting with it is done by cutting across the vat and then the long way of the vat.

### CURD PAIL.

When the curd is to be dipped from the vat, a curd pail, whose side opposite the handle is flat, is more convenient than the ordinary round pail, because the curd at the bottom can be scooped up more easily.

### VAT WHEY STRAINER.

The strainer commonly used is of metal, cylindrical in shape, about 5 inches in diameter, with a spout at the bottom which just fits the spigot opening. The strainer is placed in the vat with the spout in the spigot, which allows the whey to drain off, leaving the curd.

## METHOD OF MANUFACTURE.

### RIPENING THE MILK.

The object of ripening is to obtain the characteristic mild, sour-milk flavor and to develop the acidity necessary to coagulate the milk and bring about a separation of the whey from the curd when the coagulated milk (or coagulum) is heated. The temperature of ripening depends upon the time at which the cheese is to be made and the quantity of starter added.

Fresh milk should be set at a temperature which produces a firm, smooth, uniform curd at a time when it is desired to cut the curd. The ripening can be regulated by the temperature at which the milk is set and the quantity and kind of starter used. Experience soon will show the right combination of starter and temperature to be used for best results under existing conditions. A good, active, clean-flavored starter should be added at the rate of about 5 per cent of the skim milk and the milk allowed to set at a temperature of 60° or 70° F. This usually gives a smooth, uniform curd in from 6 to 12 hours. In case the milk is to be made into cheese the day it is received, a larger percentage of starter and a higher temperature for holding should be used to obtain the proper condition of curd.

Raw milk of good flavor, allowed to sour naturally, usually develops a well-flavored curd, but the probability of regularly obtaining a fine-flavored product is greatly increased by pasteurization and the use of a good starter. A starter of poor quality should never be used, because it does more harm than good by introducing undesirable fermentations; in fact, it would be better to depend upon the natural souring of the skim milk.

### CUTTING AND HEATING THE CURD.

The best time to cut the curd is shortly after it shows a firm and uniform coagulation, with an acidity of from 0.65 to 0.80 per cent, for at that stage a mild-flavored cheese is obtained and at the same time sufficient acid is present to give a clear separation of the whey from the curd. The object of cutting and heating is to get rid of the desired quantity of whey and to remove much of the acidity, with the least possible loss of curd. The best method of cutting the curd is to use regular cheese-curd knives which cut the curd into fairly uniform cubes from which the whey can be expelled with but small loss of finely broken particles of curd passing through the drain cloth. To break the curd or coagulum with a mechanical stirrer produces too many fine particles of curd, which are easily lost in draining.

The heat is turned under the vat when the curd is cut, and the temperature raised gradually to the desired point, the curd being

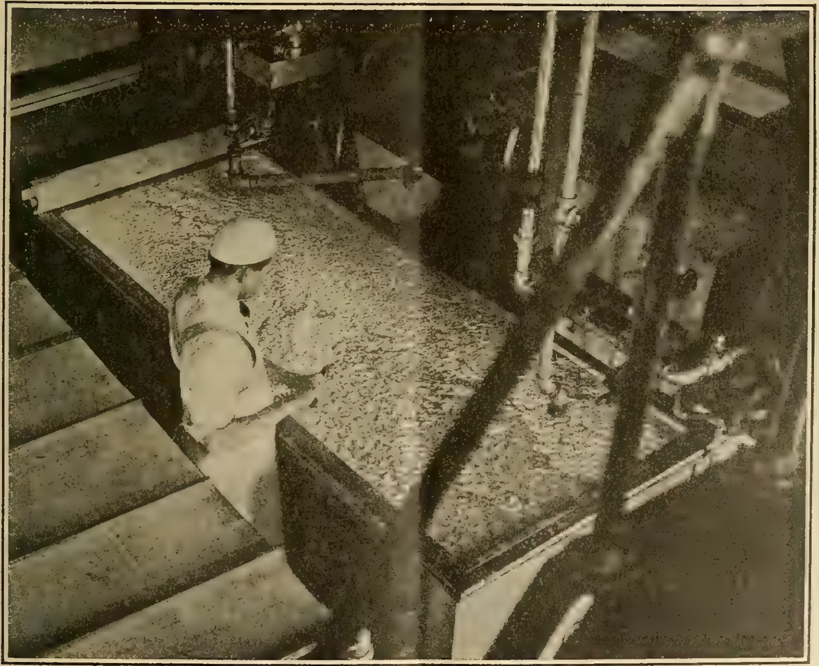

FIG. 2.—Stirring the curd during heating.

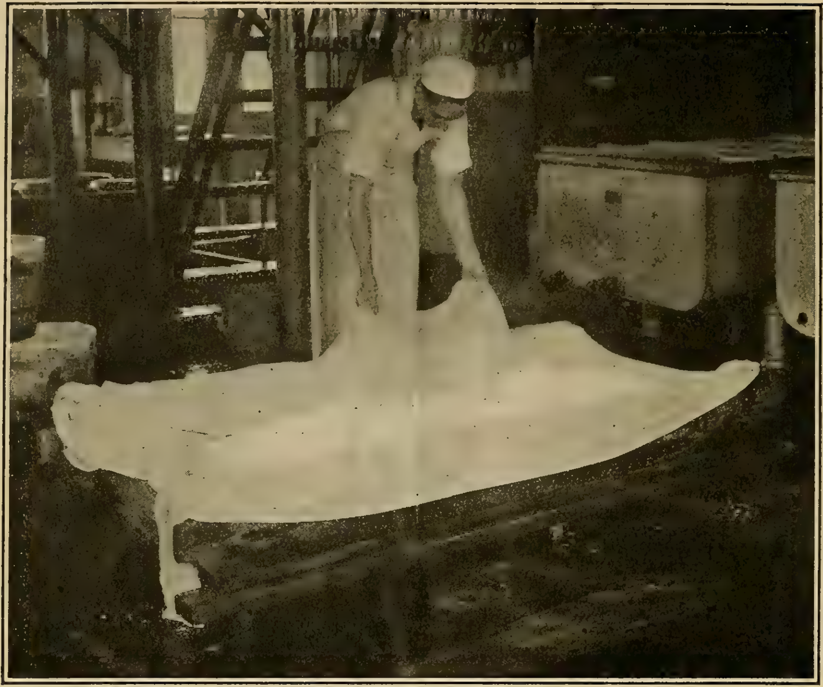

FIG. 3.—Raising and lowering the drain cloth to hasten draining.

stirred gently at frequent intervals to prevent its cooking on the sides and bottom of the vat. The texture of cottage cheese is controlled by the temperature at which the curd is heated, the length of time heated, and the extent of draining. Considerable variation is found necessary as to the temperature, time of heating, and draining, depending upon the condition of the curd. Temperatures between 90° and 105° F., depending upon the length of heating, give good results when a rather firm, smooth-textured cheese is desired. It is rarely necessary to exceed a temperature of 100° F. in making cottage cheese. To heat the curd to a higher temperature favors the more rapid expulsion of the whey and produces a dry, coarse-grained cheese. Similar results are obtained by holding the curd for a long period in the hot whey. The length of time that the curd should be held at the cooking temperature will vary from 15 to 30 minutes, depending upon the temperature used and the texture of the cheese desired. A high temperature or prolonged heating at a lower temperature produces a dry, coarse-grained cheese which is demanded by some markets. If a smooth, uniform-textured cheese is to be made, care must be taken not to heat the curd too long, especially when a high temperature is used. Experience will serve as a guide to determine the length of time and the temperature for heating. The smooth, even-textured cheese brings out the fine flavor to the best advantage, as it has none of the harshness or grittiness found in the dry, coarse-grained product. It is well to remember that the lower the temperature used for separation the smoother is the texture of the cheese. The use of a higher temperature shortens the time required for making, but much greater attention must be given to the various steps in the process of manufacture.

## DRAINING THE CURD.

When the heating has continued for the proper length of time the whey is drawn from the bottom of the vat into the cloth-lined drain rack. The greater portion of the whey passes through the drain cloth quickly, after which the remainder of the mixture of curd and whey is placed in the drain rack for the purpose of completing drainage. An occasional manipulation of the drain cloth, rolling the curd back and forth in the rack (as shown in fig. 3), hastens drainage, the extent of which depends upon the texture of the cheese desired, the temperature of heating, and the length of time the curd is heated. Except when a high temperature has been used the drainage can be controlled very easily and should continue until there is no accumulation of free whey in the finished cheese. A high temperature favors the accumulation of free whey in the finished product, unless the curd has been allowed to drain until the yield is materially reduced, and with the further probability of getting too dry a cheese. In case the draining is too rapid it can be checked by washing the curd with cold water, which hinders the expulsion of moisture. Free whey in the finished cheese gives rise to a very strong, sour flavor.

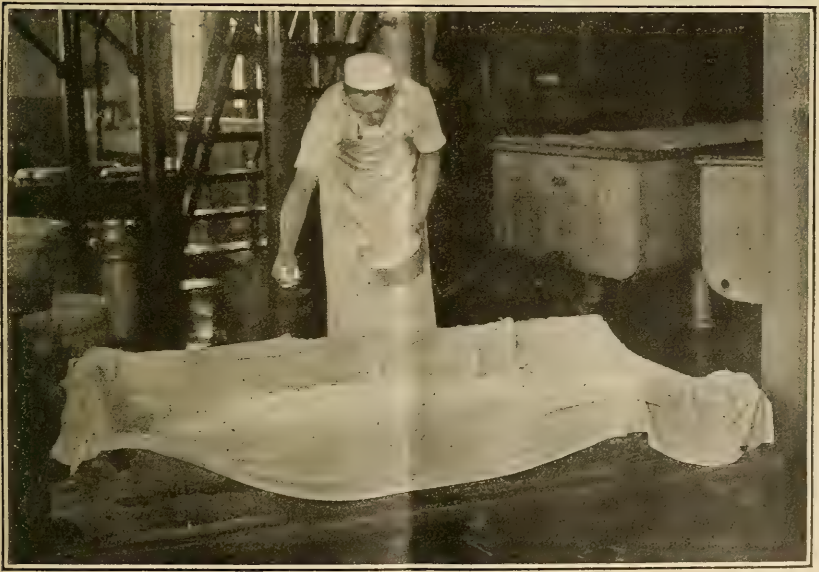

FIG. 4.—Salting the cheese.

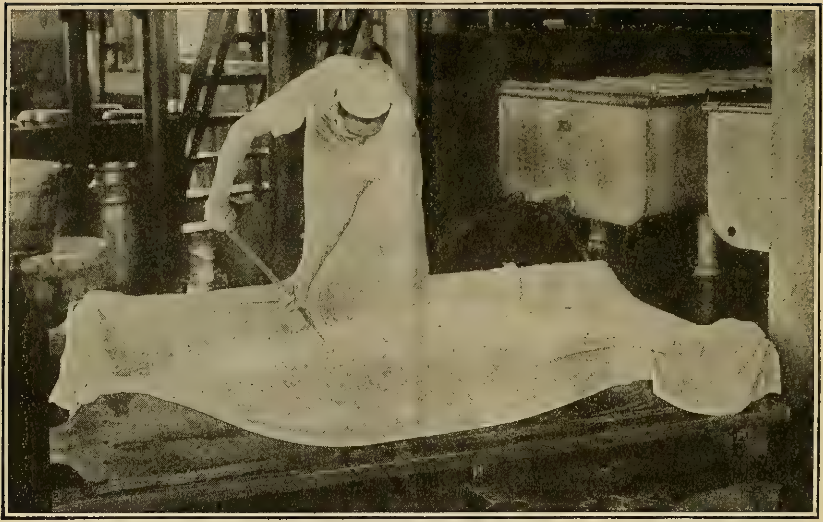

FIG. 5.—Working the salt in.

### SALTING, ETC.

When the curd has drained sufficiently, salt is added and well worked into the cheese. The rate of salting is determined by the demand, some markets desiring a light-salted and others preferring a heavy-salted cheese. One and one-quarter pounds of salt to 100 pounds of cheese gives a medium-light salted cheese satisfactory to the ordinary taste. From 3 to 4 ounces of salt to 100 pounds of milk is about the right degree of salting and perhaps may be a better basis on which to begin the work. It usually is advisable to salt rather lightly, allowing the consumers greater opportunity to prepare the cheese to suit their individual tastes.

The addition of 1 pound of sweet cream to 10 pounds of cheese greatly increases palatability and is to be recommended, especially when it is desired to build up a trade appreciating high-quality products. The cream is worked into the cheese with the salt. The additional cost of cream is small when it is considered that each pound added makes an extra pound of cheese.

### PACKING AND MARKETING.

The ideal method of marketing is to pack the cheese in the small, single-service, sanitary, paraffined paper containers, of which there are many kinds on the market (see fig. 6). The containers offer a convenient form for the dealer to handle, and are attractive to the buyer. While cartons add considerably to the cost of marketing, the extra price obtained for the product in that form usually compensates for the additional expense.

Cheese to be shipped in bulk may be packed in butter tubs (fig. 8) or in ordinary milk-shipping cans.

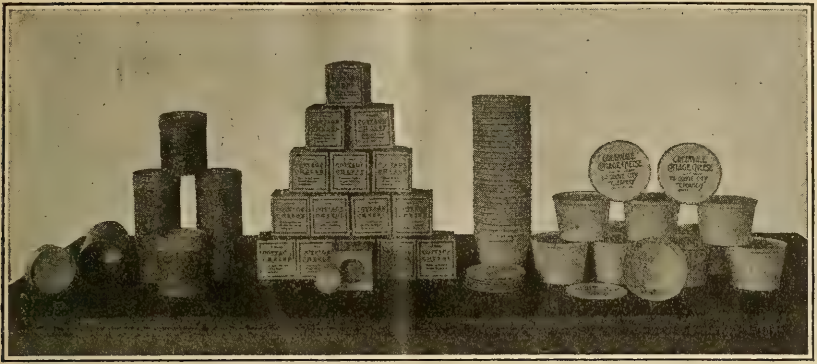

Fig. 6.—Cartons for marketing cottage cheese.

Cottage cheese always should be packed immediately after it is salted and should be marketed within a few days, as it is perishable and deteriorates very quickly at ordinary room temperatures. To insure marketing in best condition and to prevent unnecessary loss, it is important to have the cheese placed in the cooler or refrigerator immediately after it is made and to hold it at a low temperature until disposed of. Freshly made cheese should not be shipped until after it has been well cooled, because the warm curd is in a condition favoring fermentation and deterioration in quality.

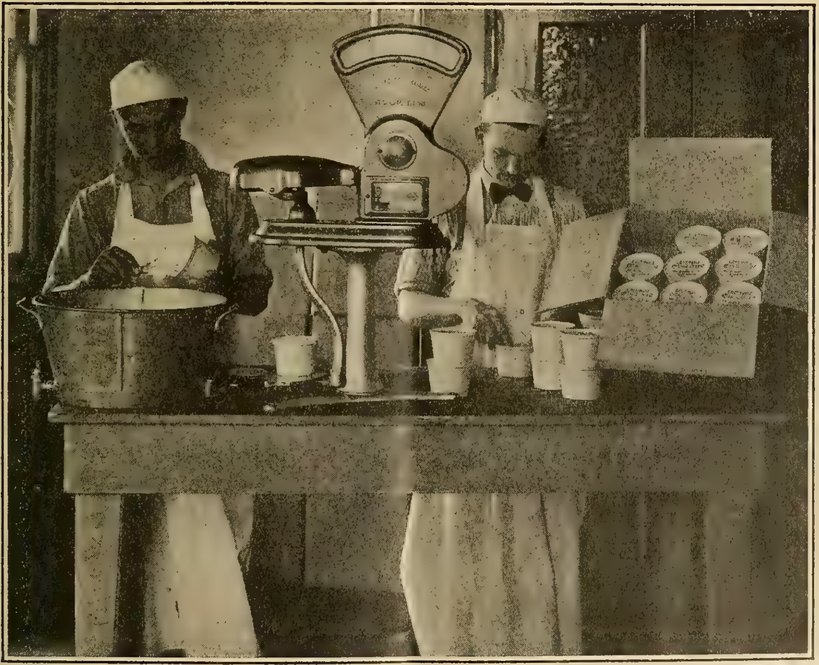

Fig. 7.—Packing the cheese in cartons.

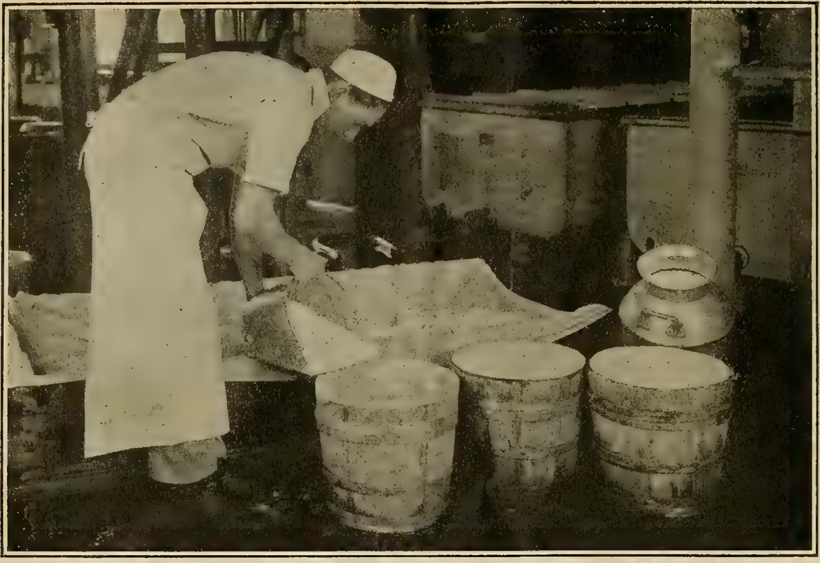

FIG. 8.—Packing the cheese in tubs.

It is advisable, therefore, to hold the freshly made cheese in the refrigerator overnight before making shipment.

## YIELD OF CHEESE.

The yield of cheese, which varies from 12 to 22 pounds for 100 pounds of milk, depends almost entirely upon the amount of moisture left in the curd, and is controlled by the method of manufacture. The factors that influence the percentage of moisture in the curd and determine the yield are—

1. Temperature of heating curdled milk (or coagulum).
2. Length of time curd is heated.
3. Extent of draining.
4. Physical condition of the skim milk after curdling.

As previously stated, a high temperature, together with prolonged heating of the coagulum, favors the rapid expulsion of moisture from the curd, which results in a low yield of dry, coarse-grained cheese. The percentage of moisture left in the curd can be controlled very well by the extent of drainage, provided too high a temperature has not been used in the process of manufacture and the curd has not been heated too long. The physical condition of the skim milk after curdling also often has a marked influence upon the resulting yield. A weak, unevenly coagulated curd, when cut, produces a large quantity of fine curd, much of which is generally lost during drainage.

The yield obtained is controlled by the method of handling, which in turn depends upon the demands of the market. The ideal cheese, which brings out the delicate, mild-acid flavor to the best advantage, is a rather firm, smooth-textured product, free from any harshness or coarseness. A yield of from 15 to 20 pounds of that kind of cheese can be obtained from 100 pounds of skim milk.

### USING BUTTERMILK FOR COTTAGE CHEESE.

While skim milk, pasteurized and ripened with a commercial starter, produces a cottage cheese of excellent quality, a high quality of cheese which will pass the most critical inspection can be made with a mixture of skim milk and buttermilk, using as high as 50 per cent of the latter. The buttermilk must be of good quality, however, and not possess the old, metallic flavor so characteristic when it has been improperly cared for. Buttermilk of good quality can be used also to good advantage for ripening pasteurized skim milk. When so used, the buttermilk should be added to the skim milk as soon as possible after coming from the churn and before there is any development of the metallic flavor. The proportion of buttermilk which may be used advantageously without reducing the quality of the cheese depends upon its quality. An old, strong flavor develops much more readily in cottage cheese containing a high proportion of buttermilk, especially if the latter has been allowed to develop the metallic flavor.

Cheese made from buttermilk or from a mixture containing skim milk and buttermilk has a much smoother body than that made from all skim milk. The body of cheese made from a mixture of the two holds up better in storage, as it does not become so dry and coarse upon standing. The smoother-textured cheese obtained when buttermilk is used is better adapted to some of the uses to which cottage cheese is put than the skim-milk product.

#### VARIATION IN METHOD WHEN BUTTERMILK IS USED.

When buttermilk from cream that was pasteurized sweet and then ripened is used by mixing it with skim milk, the method as a whole is the same as for straight skim milk except for some variation in temperature and in the method of handling, and the directions which follow are based upon that kind of material. Buttermilk from pasteurized sour cream, however, is unsuitable for this method. The pasteurization of sour cream has an injurious effect upon the condition of the buttermilk curd, depending upon the degree of acidity, the temperature used, and the method of pasteurizing, and may make it impossible to obtain satisfactory results when using the methods outlined; and buttermilk from high-acid pasteurized cream can not be handled satisfactorily by the methods given.

The skim milk and buttermilk should be mixed and set to ripen as soon as possible after the buttermilk comes from the churn. If possible, definite proportions of skim milk and buttermilk should be used for each batch of cheese, so that certain rules, determined by experience, may be followed more closely in order to manufacture a uniform product from day to day. By using buttermilk from properly pasteurized cream in combination with pasteurized skim milk the danger from disease-producing bacteria may be guarded against.

It is difficult to give any definite directions as to the temperature to be used when a mixture of skim milk and buttermilk is handled, as it is impossible to tell with any degree of accuracy how the curd will act during the process of manufacture. Buttermilk from cream ripened to a high acidity works much differently from that of cream ripened to a low degree of acidity, and because of the direct influence of the condition of the buttermilk a variation in the range of temperature is necessary. A much higher temperature for heating the coagulum can be used with a mixture containing a good proportion of buttermilk with less danger of injury to the quality of the cheese. A temperature of 90° to 115° F. produces the desired results with a mixture containing as high as 50 per cent of buttermilk, although it rarely is necessary to exceed 105° F. Additional time is required for draining the curd from a mixture containing a large proportion of buttermilk.

In salting the curd from a mixture of buttermilk and skim milk care must be taken to prevent a mottled effect on the color of the finished cheese. The curd from the skim milk is perfectly white compared to the creamy color of that from the buttermilk, owing to the butter color added to the cream. The color of the buttermilk curd gives a richer looking product, provided it is well blended throughout the cheese to prevent an unevenness of color.

The yield of cheese from a mixture of skim milk and buttermilk in the proportions indicated compares favorably with that made from straight skim milk, and is likewise affected by the same influencing factors largely under control of the maker.

The advisability of using a mixture containing much more than 50 per cent of buttermilk is doubtful. Experience indicates that the use of about 50 per cent of skim milk is necessary in order to insure the highest quality of cheese. The use of more than 50 per cent of buttermilk lessens the quality of the product, which can not be sold as the best grade of cottage cheese.

### MAKING BUTTERMILK CHEESE.

Creameries having only buttermilk of good quality can make it into a fair grade of buttermilk cheese by using the vat method or the ejector method of heating the soured buttermilk to precipitate the curd.

Because of the fineness of the curd in heating the buttermilk, extreme care must be taken to prevent breaking it up still finer. The amount of stirring required to bring the temperature of a vat full of buttermilk up to the proper point has a tendency to break up the curd so that a portion of it is liable to be lost during the process of draining. The method of running the soured buttermilk through the ejector heats the buttermilk to the required temperature with the least possible breaking up of the curd. With that method the curd is separated clearly and quickly from the whey and invariably rises to the top, facilitating a quick removal of the larger portion of the whey and making it possible to obtain the finished cheese in a short time. By means of a valve in the pipe leading from the buttermilk tank to the ejector and one in the steam pipe next to the ejector, the temperature to which the buttermilk is heated can be controlled easily. The proper temperature necessary for separating the curd clearly and quickly can be obtained readily by using a glass tumbler to catch samples of the heated buttermilk as it comes from the ejector. At the proper temperature the curd quickly rises to the top, and the whey is clear. By varying the temperature the proper degree of heat required is determined.

## COST OF MANUFACTURE.

Although the cost of manufacturing depends somewhat upon the cost of fuel and labor, it is influenced more largely by the volume of business. The table on page 14, obtained from cost-accounting records and showing averages for a three-months' period when the volume of business varied from 40,000 to 70,000 pounds of milk each month, gives a good idea of the approximate cost of manufacturing. The figures are based upon results obtained in the manufacture of cottage cheese in a commercial way at the creamery at Grove City, Pa., operated by the Dairy Division of the Bureau of Animal Industry, and, with the exception of the item of power, were obtained by making the proper tests to ascertain the expense of the different items. The labor represents the actual time of the men who did the work, figured at the rate which the average creamery would have to pay for the desired kind of help.

By making tests on the boiler to determine the number of pounds of water evaporated by 1 pound of coal, and by weighing the pounds of condensed steam required to pasteurize and later heat the milk to separate the curd, the cost of fuel was ascertained. The soft coal used cost $3.50 a ton, mine run. The cost of power is estimated at a figure considered sufficiently high to cover that item.

The quantity of water required to cool 1,000 pounds of milk was determined by measuring the actual water used to cool certain batches of pasteurized milk, and charging at the rate of 5 cents per 1,000 gallons.

Depreciation reserve was figured on the following basis:

| Apparatus. | Value. | Probable life. | Annual depreciation. |
|---|---|---|---|
| Pasteurizing vat | $500 | 10 years | $50 |
| Making vat | 100 | 4 years | 25 |
| | | | 75 |

Taking 300 as the probable number of days the vat would be used gives a daily depreciation of 25 cents. The number of days the vat was used each month and the quantity of milk handled during the same period afford a basis for determining the charge for depreciation per 1,000 pounds of milk.

The following figures were used in obtaining the charge for interest on investment:

| Apparatus. | Value. |
|---|---|
| Pasteurizing vat | $500 |
| Making vat | 100 |
| | 600 |

The interest on $600 at 6 per cent amounts to $36 a year, or $3 a month. Twenty-six runs a month, handling two batches of 2,500 pounds each, gives 11.5 cents a day, or 2.3 cents as the interest charge for 1,000 pounds of milk.

*Cost of manufacturing cottage cheese.*

| Item. | Cost per 1,000 pounds milk. |
|---|---|
| Labor | $0.790 |
| Coal | .034 |
| Power | .049 |
| Cooling water | .020 |
| Depreciation reserve | .084 |
| Interest on investment | .023 |
| Total | 1.000 |

The cost is figured on the basis of 1,000 pounds of milk because of the greater variation which would be shown when figuring on the basis of pounds of cottage cheese, owing to the variation in yield. Figuring on the basis of a yield of 18 pounds per 100 pounds of milk the cost per pound of cheese would be $0.0055, or a trifle more than one-half cent a pound, with no allowance for cost of package. These figures may be lowered with an increased volume of business; a decreased volume would raise them. In fact, actual cost accounts maintained at Grove City during a month in which 145,000 pounds of skim milk and buttermilk were made into cheese show that the cost of making cheese per 1,000 pounds of milk was only 85 cents. When only a small quantity of cheese is made the regular creamery force may be able to do the work without any additional help, which would be an item of importance in determining the actual cost.

## MARKETS AND PRICES.

In cities where large industrial concerns employ foreign labor there is already a good demand for cottage cheese, and a satisfactory market usually can be developed in other cities or localities. The market demands and prices fluctuate considerably with the condition of the milk supply and the season of the year. An overabundance of milk makes more skim milk available for cottage cheese, thus tending to lower the price. As a whole the best market at the most favorable prices is afforded during the winter, with the Lenten season calling for the heaviest demands. A lighter market in the summer season may be attributed to a greater supply of available skim milk and to the fact that warm weather makes it more difficult for dealers to handle the cheese, and in some cases prohibits the trade. Dealers who make a specialty of handling cottage cheese assert that they are in position to buy and dispose of large quantities of the product throughout the year, the price to be governed by the quality of the cheese and the condition of the milk suppply.

The Grove City Creamery began the manufacture of cottage cheese for the purpose of utilizing skim milk and buttermilk to the best advantage and providing a market, at an attractive price, for the skim milk of the patrons who wished to leave it at the creamery. Skim milk and buttermilk were used in varying mixtures, and as high as 50 per cent of buttermilk was used, the proportion depending upon the quantity and quality of the buttermilk available. The business was begun in a small way, and because of other outlets through which the raw material could be disposed of to fairly good advantage no organized effort was made to develop a market that would take care of the increased receipts of skim milk and buttermilk. The demand for the product gradually increased, however, through unsolicited inquiries, until by the Lenten season of the second year the quantity of cheese which the creamery could sell was limited only by the capacity of the cottage-cheese equipment and the quantity of raw material available. Three business houses signified their willingness to handle all the cheese that could be made during the entire summer, provided it could be delivered in good condition, an item of great importance during the warm season. At Grove City the winter price received for the cheese without the addition of cream, packed in cans or tubs furnished by the buyer, varied from 4½ to 5½ cents a pound f. o. b. the point of manufacture. This price was for a medium, dry-grained cheese whose yield was from 14 to 16 pounds from a hundred pounds of milk. The wholesale price received for a smoother-grained cheese to which cream had been added at the rate of 1 pound to 10 of cheese and which yielded from 17 to 19 pounds per hundred pounds of milk, packed in the 12-ounce, single-service containers, was 7 cents a package net at the creamery, or at the rate of 9.3 cents a pound. The 12-ounce packages, including the shipping box, cost slightly less than 2 cents apiece and, filled with cheese of good quality, retail ordinarily for from 10 to 12 cents. The demand for cheese packed in the single-service containers is from the grocery stores and meat markets in the near-by towns and gives considerable promise.

It is very desirable that a uniform quality of cheese be made at all times in order that the trade that has been built up may be retained.

## SUMMARY.

Cheese made from a good quality of skim milk or a mixture of skim milk and buttermilk is a most palatable and nutritious article of food.

Good raw material is essential in making a good product.

The pasteurization of skim milk insures a sanitary, safe food, free from all danger of disease-producing bacteria, and gives more favorable conditions for the manufacture of a uniform, high-quality cheese.

The main equipment necessary for making cottage cheese from pasteurized skim milk consists of (1) pasteurizing outfit, (2) channel-bottomed vat, and (3) draining racks, a portion or most of which already may be available at the creamery.

The skim milk is ripened to obtain the characteristic and desirable mild, sour-milk flavor, and this is best accomplished through pasteurization and the use of a commercial starter.

The method of manufacture is varied to produce cheese of the texture that the market demands.

The ideal cheese, bringing out the delicate, mild flavor to the best advantage, is a rather firm, smooth-textured cheese, with a yield of from 15 to 20 pounds of cheese to 100 pounds of skim milk.

A high-grade cheese can be made from a mixture of skim milk and good buttermilk, using some variation in the temperature and the method of handling.

The cost of manufacturing cottage cheese is low, depending upon the volume of business and the additional equipment necessary. Under ordinary conditions the cost of manufacture, not including packages, is approximately one-half cent a pound.

An excellent method of marketing the cheese is in the small, single-service, paraffined paper containers, which are most convenient for the dealer to handle and which keep the product in good condition.

A good market already exists in some cities and can be developed in any city or locality.

The normal demand and the price vary with the condition of the milk supply and the season of the year.

The creamery that makes a uniformly good quality of cheese will be affected least by changes in the market demand and will have the best outlet at the most favorable price throughout the year.

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UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 577**

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER September 14, 1917

# EXPERIMENTS IN THE CONTROL OF POTATO LEAK.[1]

By Lon A. Hawkins, *Plant Physiologist, Plant Physiological and Fermentation Investigations, Bureau of Plant Industry.*

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## THE CAUSAL ORGANISMS.

In a paper[2] on a disease of potatoes commonly known as leak, the disease was described and the literature on the subject reviewed. It was shown that the tuber rot typical of this disease could be caused by *Rhizopus nigricans* Ehrenb., as Orton[3] found, but that the causal organism was more frequently *Pythium debaryanum* Hesse. The fungus obtains entrance through breaks in the skin of the potatoes, and infection under field conditions usually takes place by some infected soil getting into wounds made in harvesting. Preliminary experiments in 1915 indicated that the disease could be controlled by carefully sorting out all wounded tubers. As the disease is of considerable economic importance in the delta region of San Joaquin County, Cal., it was considered advisable to continue these experiments. This bulletin deals with further experiments in the control of the disease, together with some additional work on the causal organism and its occurrence in the delta soils.

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[1] The work described in this bulletin was carried out as a part of the potato-disease project of the Office of Cotton and Truck Disease Investigations. The writer wishes to acknowledge his indebtedness to Mr. Carson C. Cook, of Stockton, Cal., for his hearty cooperation in this work.

[2] Hawkins, L. A. The disease of potatoes known as "leak." In Jour. Agr. Research, v. 6, no. 17, pp. 627-640, 1 fig., pl. 90. 1916.

[3] Orton, W. A. Potato diseases in San Joaquin county, California. U. S. Dept. Agr., Bur. Plant Indus. Circ. 23, 14 p. 1909.

——— Decay of potatoes due to Rhizopus nigricans. (Abstract.) *In* Science, n. s., v. 29, no. 753, p. 916. 1909.

1903°—Bull. 577—17

The fungus was isolated from the rotten tubers and inoculations made, as in the previous year. The results were similar to those obtained in 1915. Forty isolations of *Pythium debaryanum* were made in the 45 attempts. The pathogenicity of the organism was demonstrated in many instances by inoculating it into sound tubers and reisolating it after the potato had rotted. Inoculations were made by inserting small quantities of soil from various potato fields into tubers. About 50 per cent of the inoculations produced the disease from every sample of soil obtained from land which had been reclaimed and farmed for some years and had not been burned over recently.

## METHODS OF INVESTIGATION.

It is considered among the growers that potatoes would not leak if grown on new land (that is, land recently reclaimed) or on burned land (that is, land on which the peat soil had caught fire and burned more or less deeply). This theory was tested. A number of inoculations were made from samples of soil from an area that had been burned over. In no case was there any infection. Samples of soil from two areas of new land, one of which had never been farmed, while the other had been planted to potatoes the previous year, were tested. Two potatoes out of eight inoculated with soil from the land most recently reclaimed rotted, and *Rhizopus nigricans* was isolated from the tubers. All other inoculations gave negative results. Potatoes from such lands are not immune when inoculated with *Pythium debaryanum.* The apparent immunity of potatoes grown on new land or burned land seems to be due to the absence of the organism from the soil or to its presence only in limited areas.

The general plan of the experiments to demonstrate a method for the control of the disease was to sort the potatoes in the field and store the injured tubers under conditions as nearly approaching those of a commercial warehouse as possible. The sound tubers were to be shipped in the usual way. It was planned to examine the cars of sound potatoes after they reached the market or after they had been shipped and sufficient time had elapsed for the incubation of the fungus.

The farm selected for the experiments was one on which a number of crops of potatoes had been grown. Several cars of the 1916 crop had been shipped and considerable damage from leak had been reported. In the experiments here described the potatoes were harvested and sacked in the field in the usual way. They were then hauled to the levee, sorted, resacked, and the sound potatoes shipped. The tubers that had been wounded by the removal of branches (knobs) and by the digging fork were sorted out, and each lot was sacked and stored separately. The wounded tubers remained in a well-ventilated warehouse on the levee until sufficient time had elapsed for the incubation of the fungus in any inoculated tubers. They were then resorted and the number of rotten potatoes in each sack noted. The wounded tubers which had not rotted were sacked and sold.

## RESULTS OF THE EXPERIMENTS.

The first car of potatoes included in these experiments was harvested and sorted on September 4 and 5. For the car of sound potatoes (270 sacks), 349 sacks of field-run potatoes were required. Of the 79 sacks sorted out, 43 sacks were of tubers which had been wounded by the removal of knobs, and 25 sacks had been injured with the digging forks. The other 11 sacks represent shrinkage due to the drying of the potatoes and to the stretching of the sacks used in resacking.

This car of sound potatoes was shipped to Oklahoma. It was impossible for the writer to examine the potatoes after the car left Stockton, Cal. No leak had been reported by the consignee on October 1, so it is reasonable to suppose that the potatoes arrived in good condition.

The injured tubers sorted out were all stored in the warehouse until September 13, when part of them were sorted and the uninfected potatoes sold. The remaining tubers were sorted on September 18, 14 days after the first of the lot were harvested.

The second and third cars of potatoes were harvested and sorted from September 8 to 12, inclusive. For the second car (270 sacks), 326 sacks of field-run potatoes were required. Of the 56 sacks sorted out, 20 sacks were of tubers that had been injured by the digging forks, and 31 sacks were those from which knobs had been removed. The other 5 sacks represent shrinkage. The car of sound potatoes was shipped to Barstow, Cal., and was examined there by the writer six days after the potatoes had been harvested. No leaky tubers were found in any of the 20 sacks examined. Some leak was reported from Phoenix, Ariz., where the car was finally sent.

The third car of potatoes in these experiments was sorted immediately after the second. It required 325 sacks of field-run potatoes for the car of sound potatoes. Of the 55 sacks sorted out, 20 sacks were of tubers that had been injured by the removal of knobs, and 21 sacks were of those injured by the digging forks. The other 4 sacks represent shrinkage. The car of sound potatoes was shipped to Bakersfield, Cal., where it was examined six days after most of the potatoes in it had been harvested. No leaky tubers were found. The car was diverted from Bakersfield to Los Angeles, where it was reported to be leaking. It was then shipped to El Centro, Cal., where the potatoes were examined by the writer. The merchant to whom the potatoes were sold said that they arrived in fair condition and that about 1 sack in 20 contained diseased tubers. A number of sacks were examined; most of them were free from disease; in only one sack was there more than one diseased tuber, and all the diseased tubers found had been wounded with the digging fork. The amount of leak in the car was considered too small to warrant sorting.

The injured potatoes from the second and third cars were stored in the warehouse until September 18. They were then sorted and the uninfected potatoes sold. The data obtained from sorting the 1,000 sacks of potatoes as they came from the field are summarized in Table I, which includes the data already given, together with that obtained in sorting the wounded tubers.

Table I.—*Experiments with 1,000 sacks of potatoes harvested in the usual way in California, showing the results of sorting for the control of potato leak.*

| Car of sorted tubers (270 sacks). | Field-run potatoes required. | Shrinkage in sorting | Tubers injured— | | | Rotten tubers (percentage based on estimate of 200 tubers to each sack) in three lots of those injured— | | | | | | | | Injured tubers marketable when sorted. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | By removal of knobs. | By fork wounds. | In field-run lots. | By removal of knobs. | | | | By fork wounds. | | | | |
| | | | | | | Maximum. | Minimum. | Average. | | Maximum. | Minimum. | Average. | | |
| | *Sacks.* | *Sacks.* | *Sacks.* | *Sacks.* | *Per cent.* | *Number.* | *Number.* | *Number.* | *Per cent.* | *Number.* | *Number.* | *Number.* | *Per cent.* | *Sacks.* |
| No. 1.... | 349 | 11 | 43 | 25 | 19.4+ | 23 | 2 | 12.5 | 6.25 | 61 | 14 | 40 | 20 | 56.5 |
| No. 2.... | 326 | 5 | 31 | 20 | 15.6+ | 40 | 8 | 17 | 8.5 | 75 | 21 | 48 | 24 | 40 |
| No. 3.... | 325 | 4 | 30 | 21 | 15.6+ | 35 | 10 | 19 | 9.5 | 68 | 28 | 49 | 24.5 | 40 |

Table I shows that something more than 19.4 per cent of the potatoes in the first lot sorted were wounded in harvesting, either by the removal of branches (knobs) or by the digging fork. The percentage of injured tubers in the other two lots, 15.6, is not quite so great. In all, 170 sacks of potatoes out of 1,000 were injured. That such a percentage of the potatoes should be injured in harvesting indicates exceedingly poor methods. Nor does this 170 sacks represent all the injured potatoes, as the tubers injured by fork wounds were supposed to have been sorted out in the field. Much of this damage might be eliminated with proper care, but as long as the potatoes are harvested with forks it is probable that there will be a high percentage of injured tubers. The digging of potatoes with machinery is practiced very little in this region, though potato harvesters adapted to this type of soil and these conditions are said to be available.

Of the 170 sacks of injured potatoes, 104 sacks (10.4 per cent of the total of 1,000 sacks) were injured by the removal of knobs. Breaking off the knobs is a common practice in this region and is recommended by the potato buyers, as it results, of course, in a smoother potato. The tubers injured in this way are considered to be no more subject to leak than sound ones. That this view is erroneous is evident from the results obtained in these experiments. Of the first lot, 6.25 per cent of the potatoes injured in this way became infected, while in the second and third lots the percentage was somewhat higher, being 8.5 and 9.5, respectively. The practices of removing these branches and of rubbing the raw surface in the soil, as is sometimes done, or sacking them, so that soil gets into the fresh wound, are harmful. If the broken surface is exposed to the air until the wound has had time to cork over, there is much less danger of infection.

Not so many potatoes were wounded with the digging forks as by the removal of knobs, but the percentage of rotten ones among the fork-wounded tubers was much higher. Out of 1,000 sacks harvested, 66 sacks were wounded with the digging forks. Of these, from 20 to 24.5 per cent rotted. The fact that the deep wounds made with the digging fork do not dry so readily and are more liable to be filled with infected soil than wounds made by the removal of knobs seems to account for this higher percentage of infection.

## CONCLUSIONS.

It is evident from these experiments that the sorting out of all wounded tubers would practically insure a shipment from damage by this disease. It is probable that it would be impracticable in commercial work to sort carefully enough to eliminate all the wounded tubers. A few wounded potatoes slipped through in these experiments in spite of the careful sorting. It is not difficult, however, to remove 96 to 98 per cent of them. Such sorting, according to the percentages of rot occurring in the wounded tubers in these experiments, would result in an average of about one rotten potato in 10 to 25 sacks. This would be nearly complete control.

It has therefore been demonstrated that the leak may be controlled by the elimination of all wounded tubers from the shipment. The best and most economical means of accomplishing this end would be to avoid wounding the tubers in harvesting them. Wounded tubers should be sorted out and shipped separately or, better, stored for a week or more to allow the fungus to incubate, and then sorted and the uninfected potatoes sold.

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W. J. SPILLMAN, Chief

Washington, D. C. ▼ February 9, 1918

# A STUDY OF HAYMAKING CREWS AND LABOR COSTS.

By H. B. McClure, *Agriculturist.*

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In considering methods of making hay, the following questions arise: What is the best time of day to start mowing hay? How many mowers shall be used, and how many acres is it best to cut each day? How long must the hay lie in the swath before being raked? If a side-delivery rake is used, what advantage has it over the sulky rake? How many men are needed to haul in hay from the field, and is it more economical with a given acreage to use a hay loader than to load by hand? How many men are needed for storing hay in the barn or to work on the stack?

These and similar questions are of importance to American farmers in general, since the production of hay is a more or less important farm enterprise in most sections of the country, and since the labor cost, the largest item of expense in hay production, is largely made up of the cost of haymaking. It was to throw light on such questions that this study of the common practices of hay growers was made. Over 500 farms, in different hay-growing districts, were visited, and figures were obtained covering haying operations for timothy, timothy and clover, alfalfa, and prairie hay. (See fig. 1.)

Some farmers, when asked to describe the method used in making hay, will reply: "Oh, it is very simple. I just cut the hay down, rake it up, and put it in the barn or stack." Such farmers, though having a very indefinite method, nevertheless can give the number of acres cut per day with a mower and other information regarding a normal day's work for various haying operations. This information, while of value in finding out the cost of making hay for the locality, is of little value in studying the methods of making hay and comparing their efficiency.

## SCOPE OF BULLETIN.

This bulletin is not intended to show the cost of making hay in any particular locality or section, but rather to show the effects of different methods of distribution of labor in the crew, for the purpose of impressing upon the hay grower the importance of working out and using a detailed system that will be most applicable to his individual farm.

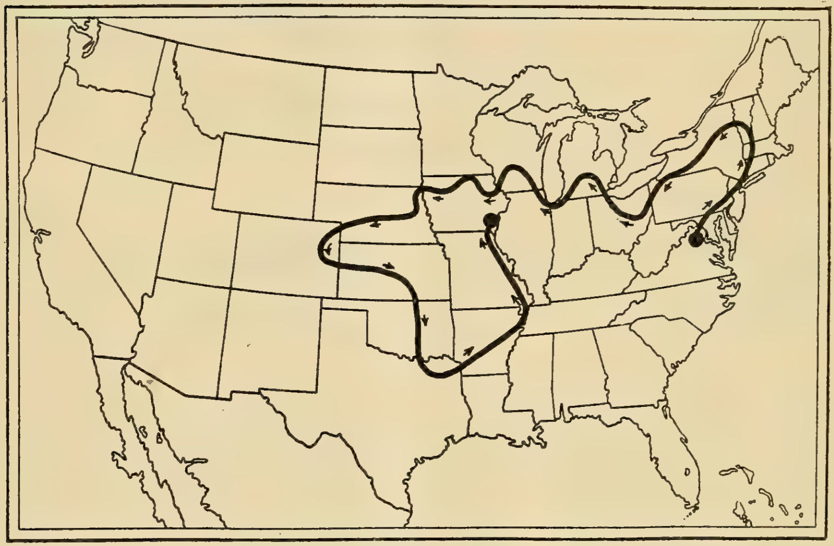

FIG. 1.—Route covered in making this study.

In order to assist the hay grower to devise such a method, a few selected methods are described in detail. These illustrate the four general systems in use in making hay. It is not necessary or possible, in this brief survey, to go into the details of the almost infinite variety of hay-making methods used for different kinds of hay under varying yields, sizes of crews, and kinds and extent of machinery used.

The methods used as illustrations are, for the most part, common in their localities, represent small, medium, and large-sized crews, and, as a rule, the best practice in vogue. They are presented in order of increasing size of crews. That the grower may be able to compare the cost and efficiency of the method he is using with those described, a uniform rate of 20 cents per hour for man labor and 10 cents per hour for horse labor has been used. These rates vary somewhat in actual practice, though that for man labor will be found to be fairly accurate for the hay-growing section as a whole.

## EXPLANATION OF SYMBOLS USED IN WORK CHARTS.

In order to compare one method of haying with another, it is necessary for the reader to have some way of fixing in mind easily and quickly the different operations of the crew. Straight bars are used often in work charts to show variations in the seasonable distribution of labor, etc., but while this method is effective within certain limits, it is not applicable in this instance, since, if straight bars were used for the many different operations of haymaking, the chart would at once become confusing and leave but little impression on the mind. For these reasons, symbols have been used which are at once simple and suggestive of the operations they represent. These symbols are used on the charts so that the reader can see at a glance the time each operation starts and stops, the number of men, horses, and machines used, and the time lost in each operation.

For example, the symbol representing mowing is m; that representing raking, r. Thus the first letter of the name of each operation represents that operation on the labor chart. (See work chart 1.) These letters are repeated, extending horizontally, to indicate the lapse of time occupied by the operation. Roman capitals (A, B, C, etc.) are used to designate individual men of the crew, and small Roman letters (a, b, c, etc.) to designate individual two-horse teams. Boys are indicated by capital letters in italics (*A*, *B*, *C*, etc.), and single horses used for raking, etc., by small italics (*a*, *b*, *c*, etc.). Where the same individual takes part in two different operations during the same hours, such as pitching in the field and unloading at the barn, the symbol used to designate this individual is inclosed in parentheses opposite the second operation.

If A and team (a) mow in the forenoon and rake in the afternoon, they are designated by the same letters throughout the day. If any man or team works in the forenoon, but not in the afternoon, the letters used for the man or team in the morning are not given to other men or teams in the afternoon. Thus, the total number of men and teams used during the day can be seen at a glance.

In using the following work charts to determine the method best adapted to his own needs, the farmer always should bear in mind these important factors:

(1) The average number of days available for haymaking in his locality.
(2) The number of acres or tons to be handled daily.
(3) The number of men and horses available for the work.
(4) The type of machinery to be used.

Under each system of making hay the methods have been arranged according to size of crew, the smallest crew first.

## CREW CAPACITY.

Apparent discrepancies will be noted in the haying operations, such as amount mowed, raked, pitched, etc., per hour. Variation in the amount mowed is caused by difference in cut of mowers, in yield and character of the hay, and in speed of the mower team. The amount of hay pitched on by hand varies considerably with the ability of the pitcher. The length of haul to barn also makes considerable difference in the amount done per day.

Most of the methods described are in more or less common use in certain localities, but some of the systems, where the labor per ton is rather low, are those used by isolated farmers who have worked out the best methods for their respective conditions.

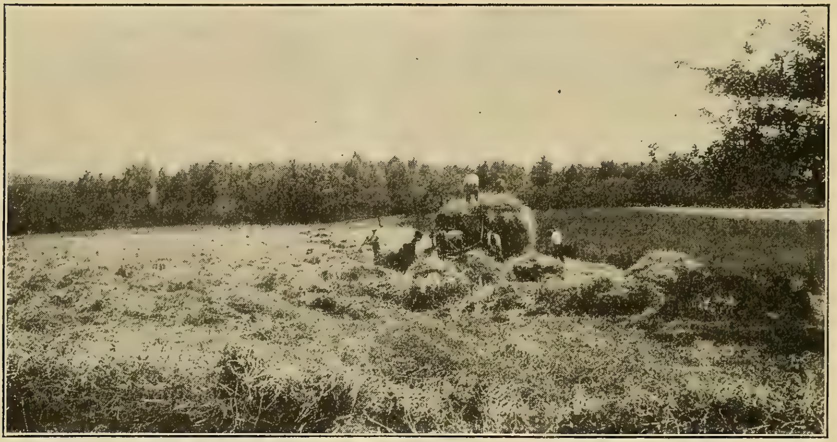

FIG. 2.—Loading wagon with hand forks. This calls for irksome man labor and is the most expensive method of getting hay on the wagon. Economical for small acreage only.

## SYSTEMS OF MAKING HAY.

Haymaking may be divided into four general systems, as follows: (1) Wagon loaded by hand and unloaded with horse fork into barn; (2) wagon loaded by hay loader and unloaded with horse fork at barn; (3) hay put into stack with push rakes and stacker; (4) hay baled from the windrow with horse or power press.

### System 1.—Hand Loading.

System 1, in which the wagon is loaded by hand forks, is the oldest system, and is used extensively and almost exclusively in the eastern part of the tame hay area. It requires but little outlay for machinery and is best adapted to farms having a small acreage of hay. It is doubtful if it would pay to buy hay loaders for many such small farms, even where the meadows are not too hilly. When hay is cured in the cock it is necessary to use this system. (See fig. 2.)

The three-man crew is most commonly used for acreages up to 30 acres. For a larger acreage up to 60, the five-man or six-man crew is generally used.

### METHOD 1.

Method 1 can be recommended only for cases in which a small acreage of legume hay is grown. The man who used this method grew sugar beets as the principal crop, and the haying interfered little with the necessary work required in the beet field. In this system, one man works nearly all the first day in the hay field, and the next day two men work in the morning only. If this system is used, the hay should all be made in a week or ten days, in order to get the hay all made before it becomes too mature. The method is not to be recommended in sections subject to frequent rainfall. (See fig. 3.)

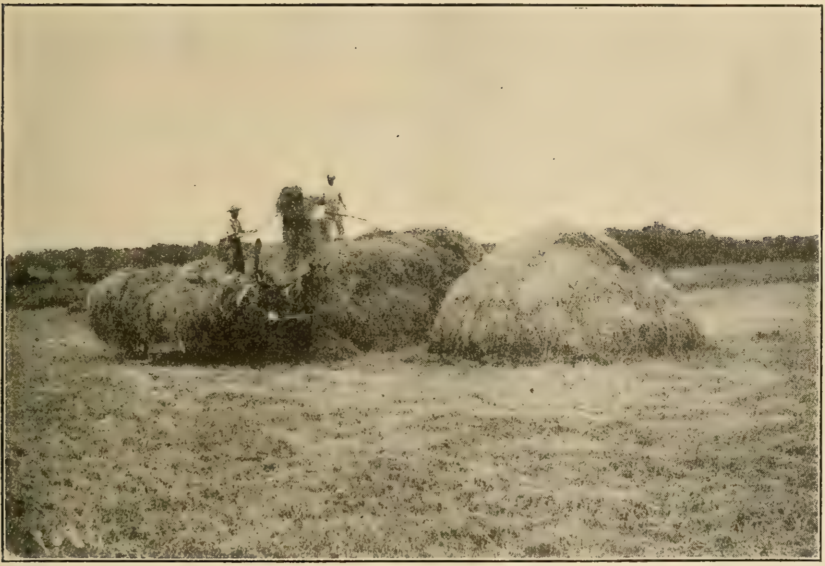

FIG. 3.—Pitching hay on to the stack by hand. This is a slow and costly method of unloading hay and should be used only when the acreage is small.

To facilitate interpretation of the work charts, the first one will be described here in detail. A here represents the man and a his team, which draws the mower in the forenoon and the sulky rake in the afternoon of the first day. The chart shows that the mower runs from 8 o'clock in the morning until noon. In the afternoon A, with his team a, rakes from 3.30 until 6 p. m. B does no work at haying the first day, and he and his team b are available for other work, such, for instance, as cultivating corn. The second day B pitches hay onto the wagon to A, who builds the load and hauls to the barn with team a. A and B unload. One works in the mow and the other unloads the hay with a pitchfork.

WORK CHART 1.—*Alfalfa loaded and unloaded by hand (Colorado).*

[This method is adapted to about 20 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| First day: | | | | | | | | | | | | | | | |
| Mowing........ | A | a | | | m m | m m | m m | m m | | | | | | | |
| Raking........ | A | a | | | | | | | | | | r | r r | r r | |
| Second day: | | | | | | | | | | | | | | | |
| Hauling....... | A | a | h h | h h | h h | h h | h h | h h | | | | | | | |
| Pitching...... | B | | p p | p p | p p | p p | p p | p p | | | | | | | |
| Unloading..... | (AB) | | u u | u u | u u | u u | u u | u u | | | | | | | |

Two men and two horses put up 2 tons (2 acres) per day, or 4 tons every other day. Yield 1 ton per acre. Man-hours 4.61, team-hours 3.12 per acre. Labor cost, per ton, $1.546.

METHOD 2.

This small 2-man crew is limited to 30 acres of tame hay in a haying season lasting 10 working days. If the haul is short and the pitcher is a fairly strong man, 4½ tons can be put into the barn each afternoon. When unloading, the man who sticks the fork will have to drive team on hayfork, using a short ladder to reach the ground, unless a woman, boy, or girl drives the team. If the hay is not tedded, the labor cost will be reduced about 18 cents per ton. This is a very good method for a small acreage of hay when two men can devote nearly all day to haying.

WORK CHART 2.—*Timothy and clover loaded by hand and unloaded with horse fork (Wisconsin).*

[This method is adapted to 30 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | | | m m | m m | m m | | | | | | | |
| Tedding......... | B | b | | | t t | t t | | | | | | | | | |
| Raking.......... | B | b | | | | | r r | r r | | | | | | | |
| Hauling......... | A | a | | | | | | | | h h | h h | h h | h h | h h | |
| Pitching........ | B | | | | | | | | | p p | p p | p p | p p | p p | |
| Unloading....... | (AB) | b | | | | | | | | u u | u u | u u | u u | u u | |

Two men and four horses put up 4.5 tons (3 acres) per day. Yield 1.5 tons per acre. Man-hours 3.77, team-hours 3.77 per ton. Labor cost, per ton, $1.508.

## METHOD 3.

This is a very common method, involving the use of the tedder, which can be used on areas up to 40 acres. The hay is tedded in the forenoon, and after dinner is raked with a side-delivery rake. When raking is finished, the man raking takes his team to the barn, involving a brief interval of time, and helps load and unload the remainder of the afternoon.

WORK CHART 3.—*Timothy and clover loaded by hand; unloaded with horses* (*Wisconsin*).

[This method is used on 40 acres of hay.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Mowing.......... | A | a | | | | m m | m m | m m | | | | | | | | |
| Tedding......... | B | b | | | | t t | t t | t t | | | | | | | | |
| Raking.......... | A | a | | | | | | | | r r | r r | | | | | |
| Pitching........ | C | | | | | | | | | p p | p p | p p | p p | p p | p p | |
| Pitching........ | A | | | | | | | | | | | p | p p | p p | p p | |
| Hauling......... | B | b | | | | | | | | h h | h h | h h | h h | h h | h h | |
| Unloading....... | (CB) | (b) | | | | | | | | u u | u u | u | | | | |
| Unloading....... | (CBA) | a | | | | | | | | | | u | u u | u u | u u | |

Three men and four horses put up 6 tons (4 acres) per day. Yield, per acre, 1.50 tons. Man-hours 4, team-hours 3 per ton. Labor cost, per ton, $1.40.

## METHOD 4.

This crew works a little faster than the ordinary three-man crew. That 6 tons can be pitched by one man (C), with the help of A the last two hours in the afternoon, is due to the fact that the rake is used to put the hay into small bunches, thus enabling the pitchers to make better time. If the hay were not bunched, it would be necessary to mow in the morning, so that A could help pitch all afternoon. This method will handle 4 acres a day, or 40 acres in 10 working days.

WORK CHART 4.—*Timothy and clover loaded by hand and unloaded with horses* (*Iowa*).

[This method is adapted to 40 acres of hay.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | | | | | | | m m | m m | m m | | | |
| Raking.......... | A | a | | | r r | r r | r r | | | | | | | | |
| Bunching........ | A | a | | | | | | b b | | | | | | | |
| Hauling......... | B | b | | | | | | | | h h | h h | h h | h h | h h | |
| Pitching........ | C | | | | | | | | | p p | p p | p p | p p | p p | |
| Pitching........ | A | | | | | | | | | | | | p p | p p | |
| Unloading....... | (BC) | (b) | | | | | | | | u u | u u | u u | | | |
| Unloading....... | (ABC) | a | | | | | | | | | | | u u | u u | |

Three men and 4 horses put up 6 tons (4 acres) per day. Yield, 1.50 per tons per acre. Man-hours 3.16, team-hours 2.33 per ton. Labor cost, per ton, $1.089.

## METHOD 5.

A good system of management for a small crew, when it is desired to cut hay late in the afternoon. The dew or rain falling on hay thus freshly cut will not be as injurious as if the hay were partly cured. It will require a 6-foot mower and a good, strong team to cut 6 acres in 4 hours. However, the team can be speeded up, as the mowing is done in the coolest part of the day.

The outstanding objection to this method is the long hours in the afternoon for A, who works 8 hours after 1 o'clock. In such a case, the farmer himself would naturally do the moving, since he could hardly expect a hired man to work so late.

WORK CHART 5.—*Timothy and clover loaded by hand and unloaded with horse fork* (*New York*).

[This method is used on 30 acres of hay, but is adapted to 60 acres.]

| Operation | Men. | Teams | Time required | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Mowing.......... | A | a | | | | | | | | | | | | m m | m m | m m | m m | |
| Raking.......... | A | a | | | | | | | | r r | r r | r r | | | | | | |
| Bunching........ | A | a | | | | | | | | | | | b b | | | | | |
| Pitching........ | B | | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | | | | |
| Pitching........ | C | | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | | | | |
| Hauling......... | D | b | | | h h | h h | h h | h h | | h h | h h | h h | h h | h h | | | | |
| Unloading....... | (BCD) | (b) | | | u u | u u | u u | u u | | u u | u u | u u | u u | u u | | | | |

Four men and 4 horses put up 9 tons (6 acres) per day. Yield, 1.50 tons per acre. Man-hours 3.87, team-hours 1.89 per ton. Labor cost, per ton, $1.152.

### METHOD 6.

This crew consists of 5 men and 6 horses. It puts up 10 acres of hay a day, and hence could care for 100 acres in ten working days, the usual length of the haying season (one cutting). All of the men work all day at haying except the man raking, who works only in the afternoon. On most farms producing 100 acres of hay, there is always other work to be done besides haying, and this method allows one man to do other farm work in the morning.

A weakness of this method is that when there is a heavy dew the crew may be idle an hour or two in the morning. In order to obviate this and get in a full day's work, enough hay should be bunched late in the afternoon to keep the crew busy in the morning until the dew is gone and the hay is in proper condition to be taken up from the windrow.

The labor cost for this crew is $0.93 per ton, which is very low for this system.

If another similar crew is used one rake will rake for both crews and will be kept busy all day.

WORK CHART 6.—*Timothy and clover loaded by hand, unloaded with horses (New York).*

[This method is adapted to 100 acres of hay.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | B | b | | | | | | | | r r | r r | r r | r r | r r | |
| Hauling......... | C | c | | h h | h h | h h | h h | h h | | h h | h h | h h | h h | h h | |
| Pitching........ | D | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching........ | E | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Unloading....... | (CDE) | (c) | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |

Five men and 6 horses put up 15 tons (10 acres) per day. Yield per acre, 1.50 tons. Man-hours 3.0, team-hours 1.66 per ton. Labor cost, per ton, $0.932.

### METHOD 7.

This is a rather expensive method, considerable time being lost while waiting for the dew to go off in the morning. Hay is cut in the morning and tedded in the afternoon, and raked the following morning. The hauling crew is one man short in the forenoon, and there is a loss of 2 hours by man and team after the tedding is finished. Two loads are hauled in by noon, and in the afternoon the remainder of the 6 tons are hauled in. This is not a speedy crew, but is fairly representative of crews on some farms having 40 to 50 acres of timothy and clover hay. In the afternoon, B pitches and team b is used at the barn to unload. E remains at the barn to drive team on hay rope. E is an old man not able to pitch in the field.

WORK CHART 7.—*Timothy and clover loaded by hand and unloaded with horse fork (New York).*

[This method is adapted to 40 acres of hay.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | | m m | m m | m m | m m | | | | | | | |
| Tedding......... | A | a | | | | | | | | t t | t t | t t | | | |
| Raking.......... | B | b | | | | r r | r r | r r | | | | | | | |
| Hauling......... | C | c | | | | h h | h h | h h | | h h | h h | h h | h h | h h | |
| Pitching........ | D | | | | | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching........ | B | | | | | | | | | p p | p p | p p | p p | p p | |
| Unloading....... | E | | | | | u u | u u | u u | | u u | u u | u u | u u | u u | |
| Unloading....... | (CD) | (c) | | | | u u | u u | u u | | | | | | | |
| Unloading....... | (BCD) | b | | | | | | | | u u | u u | u u | u u | u u | |

Five men and 6 horses put up 6 tons (4 acres) per day. Yield, 1.5 ton per acre. Man-hours 6.5, team-hours 3.83 per ton. Labor cost, $2.06 per ton.

## METHOD 8.

This method, employing 6 men and 4 horses, is used by a farmer in Pennsylvania. Only 2 men (both of whom work on the farm all the year round) work all day at haying. The other 4, hired for the afternoon only, are transient labor.

When load reaches the barn, it is left standing to be unloaded, while team goes to the field with a second wagon to be loaded. Three men remain at the barn all of the time and are idle over half of the time. The 2 pitchers are idle while team goes to and returns from barn. The method is given to illustrate poor labor management. A way to remedy this would be to do away with the barn crew entirely and have the two pitchers go to the barn and help unload, or to provide teams and wagons enough to keep the barn crew busy. This, in turn, would necessitate using the mower and rake longer.

WORK CHART 8.—*Timothy and clover loaded by hand and unloaded with horse fork (Pennsylvania.)*

[This method is adapted to 50 acres of hay.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing......... | A | a | | | m m | m m | m m | m m | | | | | | | |
| Raking......... | B | b | | | r r | r r | r r | r r | | | | | | | |
| Hauling......... | A | a | | | | | | | | h h | h h | h h | h h | h h | |
| Pitching........ | B | | | | | | | | | p p | p p | p p | p p | p p | |
| Pitching........ | C | | | | | | | | | p p | p p | p p | p p | p p | |
| Unloading....... | D | b | | | | | | | | u u | u u | u u | u u | u u | |
| Unloading....... | E | | | | | | | | | u u | u u | u u | u u | u u | |
| Unloading....... | F | | | | | | | | | u u | u u | u u | u u | u u | |

Six men and 4 horses put up 7.5 tons (5 acres) per day. Yield, 1.50 tons per acre. Man-hours 5.06, team-hours 2.4 per ton. Labor cost, $1.49.

### METHOD 9.

This is a one-crew system used on a farm in New Jersey, where over 500 acres of alfalfa are grown. It is a very good method for sections where unfavorable weather makes it necessary to cure in the cock under hay caps. In this instance, the 3 men cocking were experienced haymakers who did about as much work as 4 green, transient laborers would do. (See fig. 4.)

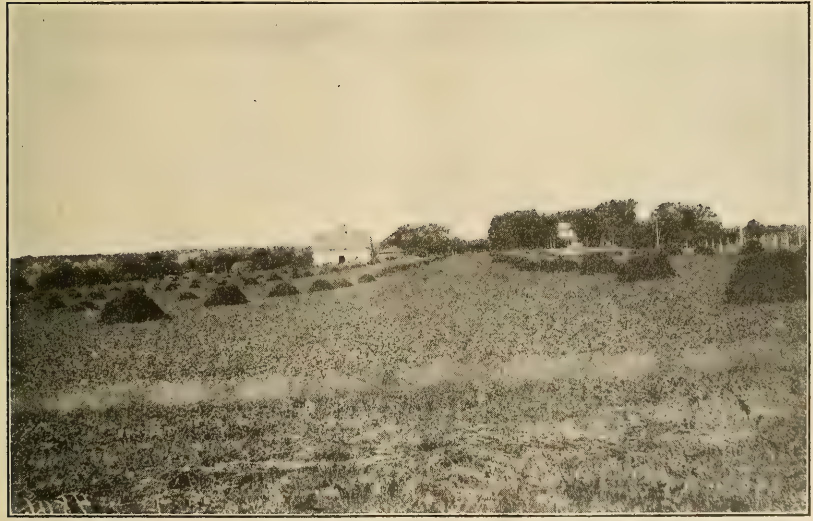

FIG. 4.—Legume hay curing in well-made cocks. Hay put into the cock when well wilted will turn a certain amount of rain, but hay caps should be used if the cocks are to stand several days.

WORK CHART 9.—*Alfalfa cured in the cock; loaded by hand and unloaded with horse fork This crew is one unit on a farm where 500 acres of alfalfa are grown (New Jersey).*

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | B | b | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Cocking......... | C | | | c c | c c | c c | c c | c c | | c c | c c | c c | c c | c c | |
| Cocking......... | D | | | c c | c c | c c | c c | c c | | c c | c c | c c | c c | c c | |
| Cocking......... | E | | | c c | c c | c c | c c | c c | | c c | c c | c c | c c | c c | |
| Capping and uncapping cocks. | F<br>G | c | | c c<br>c c | c c<br>c c | c c<br>c c | c c<br>c c | c c<br>c c | | c c<br>c c | c c<br>c c | c c<br>c c | c c<br>c c | c c<br>c c | |
| Pitching........ | H | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching........ | I | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching........ | J | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching........ | | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Hauling......... | K | d | | h h | h h | h h | h h | h h | | h h | h h | h h | h h | h h | |
| Hauling......... | L | e | | h h | h h | h h | h h | h h | | h h | h h | h h | h h | h h | |
| Unloading....... | M | | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |
| Unloading....... | N | | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |
| Unloading....... | O | | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |
| Unloading....... | [1]P | | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |

[1] Operates gasoline engine used for unloading.

Fifteen men, 1 boy, and 9 horses put up 27 tons (15 acres) of hay per day. Yield, 1.80 tons per acre. Man-hours 5.42, horse-hours 3.07 per ton. Labor cost, $1.39 per ton. Cost of labor and engine charges, $1.43 per ton.

### System 2.—Loading With Loader.

In system 2 hay is loaded with hay loader and unloaded with horse fork.

The loader, when used, will be found usually on farms with a hay area of from 60 to 150 or more acres. For such areas the labor cost with the loader usually is less than that of loading by hand, and more work will be done by a crew using a loader than by the same crew pitching by hand. The loader is used to best advantage if a side delivery rake is used, for the reason that after but one round has been made with the rake the loader can start. (See fig. 5.)

When the yield is heavy the rake can be dispensed with and the hay taken directly from the swath. The loader adds considerably to the cost of the hay equipment, and repairs are quite an item if it is not properly handled.

Many farmers say that hired help do not like to use the loader, because it makes the work of building the load a strenuous job. Slings can be used to advantage with the loader.

### METHOD 10.

This method was found on a farm where help was scarce and the crew short. The first load is put on by one man, the other raking with side-delivery rake. When load is on, the second load has been raked. Both men go to barn and unload. The second, and every alternate load thereafter, both men load. They change places every other load. The team on wagon needs no driver when loading. This method calls for very hard work. The amount of hay made is above the average for a two-man crew.

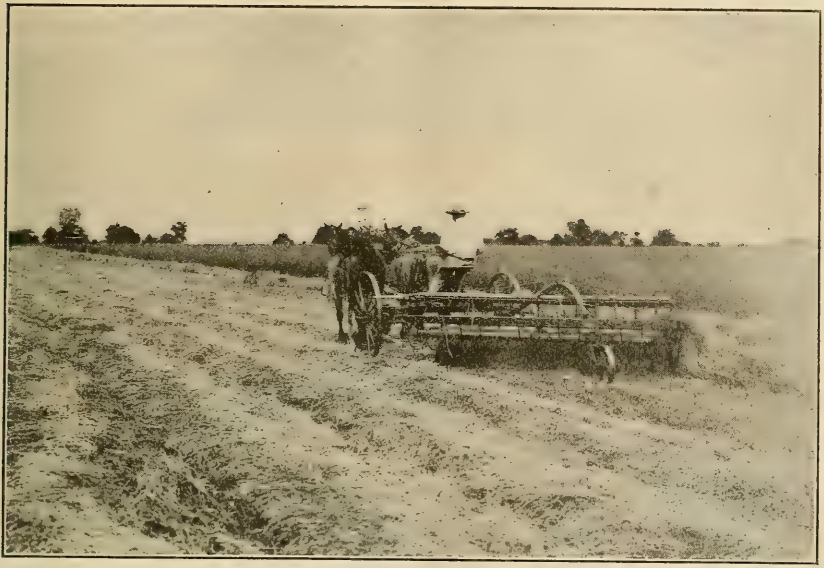

FIG. 5.—The side-delivery rake in operation. It puts the hay in loose windrows which allow a free circulation of the air. If used, however, when the hay is nearly cured, there is liable to be a large leaf loss, especially with legume hay.

WORK CHART 10.—*Timothy and clover loaded with loader and unloaded with horse fork (Ohio).*

[This method is adapted to 60 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | | | | | | | |
| Raking.......... | A or B | a | | | | | | | | r r | r r | r r | r r | r r | r r | |
| Hauling......... | A or B | b | | | | | | | | h h | h h | h h | h h | h h | h h | |
| Unloading....... | (AB) | (b) | | | | | | | | u u | u u | u u | u u | u u | u u | |

Two men and four horses put up 9 tons (6 acres) per day. Yield, 1.50 tons per acre. Man-hours 1.83, team-hours 1.83 per ton. Labor cost, per ton, $0.732.

### METHOD 11.

This method is in common use and adapted to an acreage up to 80 acres. Three men work on the wagon. One drives and the other two build the load, and 12 tons are put into the barn in 6 hours. This is perhaps the maximum amount of hay that a crew of this size can handle in one afternoon. In order to accomplish this amount of work, large hay racks will have to be used, so that more than the average amount of hay is hauled per load. It will also be necessary that the distance from the field be short, say not over a quarter of a mile. (See fig. 6.)

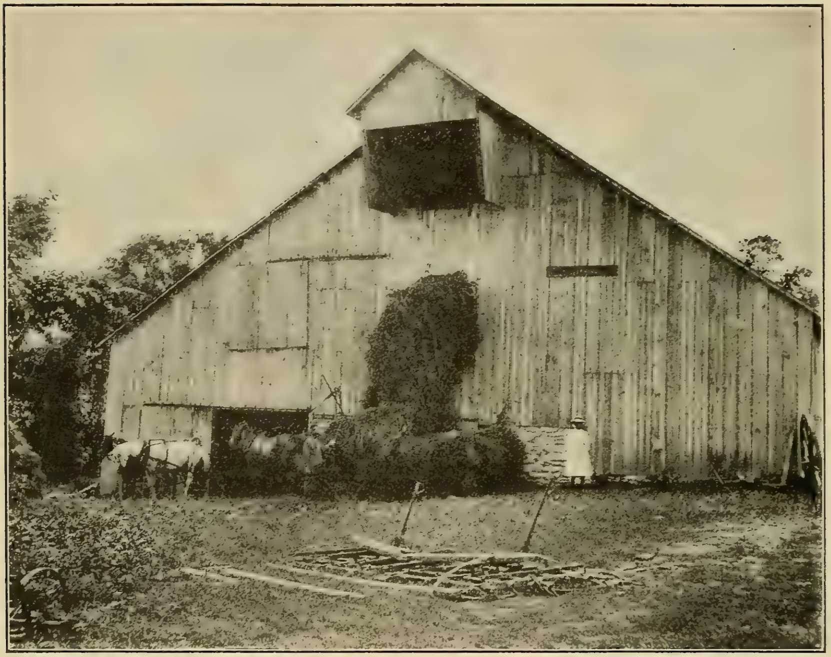

FIG. 6.—Unloading hay at the barn with horse power. The horse fork eliminates man labor and makes a considerable saving in time in unloading.

WORK CHART 11.—*Timothy and clover loaded with loader; unloaded with horses (New York).*

[This method is adapted to 80 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Mowing.......... | A | a | | | m | m m | m m | m m | | | | | | | | |
| Mowing.......... | B | b | | | m | m m | m m | m m | | | | | | | | |
| Raking.......... | B | b | | | | | | | | r r | r r | r r | r r | r r | | |
| Loading......... | A | | | | | | | | | l l | l l | l l | l l | l l | l l | |
| Loading......... | C | | | | | | | | | l l | l l | l l | l l | l l | l l | |
| Hauling......... | D | a | | | | | | | | h h | h h | h h | h h | h h | h h | |
| Unloading....... | (ACD) | (a) | | | | | | | | u u | u u | u u | u u | u u | u u | |

Four men and 4 horses put up 12 tons (8 acres) per day. Yield, 1.50 tons per acre. Man-hours 2.50, team-hours 1.50 per ton. Labor cost, per ton, $0.80.

### METHOD 12.

This method is used on a farm growing 25 acres of hay. Only one man works in the forenoon—from 11 to 12 o'clock—raking. The hay is cut late in the afternoon, and the crew hauling from field work from 12.30 until 7 p. m., getting in 7.5 tons, which is below the average for such a crew. A long haul to barn or a slow working crew must account for the fact that so little hay is hauled in in 6.5 hours.

WORK CHART 12.—*Timothy and clover loaded with loader; unloaded with horse fork (New Jersey).*

[This method is adapted to 50 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Mowing.......... | A | a | | | | | | | | | | m m | m m | m m | m m | m | |
| Raking.......... | A | a | | | | | | r r | | r r | r | | | | | | |
| Hauling......... | B | b | | | | | | | h | h h | h h | h h | h h | h h | h h | | |
| Loading......... | C | | | | | | | | l | l l | l l | l l | l l | l l | l l | | |
| Loading......... | D | | | | | | | | l | l l | l l | l l | l l | l l | l l | | |
| Unloading....... | (BCD) | (b) | | | | | | | u | u u | u u | u u | u u | u u | u u | | |

Four men and 4 horses put up 7.5 tons (5 acres) per day. Yield, 1.5 tons per acre. Man-hours 3.53, team-hours 1.80 per ton. Labor cost, per ton, $1.066.

### METHOD 13.

This method is in common use in New York on farms where the hay area is 60 acres or less. The objection to this method is that one man (A) gets through working (raking) at 4 o'clock in the afternoon and must remain idle or find some other profitable work to do with his team for two hours, a thing not always feasible. In the forenoon B, C, and D can work on other crops. A boy can be substituted for the man driving team while loading without lessening the efficiency of the crew.

WORK CHART 13.—*Timothy and clover loaded with loader; unloaded with horse fork (New York).*

[This method is adapted to 60 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m | m m | m m | m m | m m | | | | | | | |
| Raking.......... | A | a | | | | | | | | r r | r r | r r | | | |
| Hauling......... | B | b | | | | | | | | h h | h h | h h | h h | h h | |
| Loading......... | C | | | | | | | | | l l | l l | l l | l l | l l | |
| Loading......... | D | | | | | | | | | l l | l l | l l | l l | l l | |
| Unloading....... | (BCD) | (b) | | | | | | | | u u | u u | u u | u u | u u | |

Four men and 4 horses put up 6 tons (6 acres) per day. Yield, 1 ton per acre. Man-hours 3.75, team-hours 2.08 per ton. Labor cost, per ton, $1.166.

### METHOD 14.

This crew, using two teams to haul from the field, and a barn crew of two men, put in about the same amount of hay as the four-man crew in method 11. The small yield (only 1.25 tons per acre) and a longer haul made it necessary to use the second team for hauling in. This method is in common use in Iowa.

Compare the labor required and cost of this method with No. 16, in which the tedder is used. In both methods the hay is not raked, but is taken directly from swath with loader.

WORK CHART 14.—*Timothy loaded with loader and unloaded with horse fork (Iowa).*

[This method is adapted to 100 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | | | | | | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | | | | | | |
| Hauling.......... | A | a | | | | | | | | h h | h h | h h | h h | h h | |
| Hauling.......... | B | b | | | | | | | | h h | h h | h h | h h | h h | |
| Loading.......... | C | | | | | | | | | l l | l l | l l | l l | l l | |
| Unloading....... | D | | | | | | | | | u u | u u | u u | u u | u u | |
| Unloading....... | E | | | | | | | | | u u | u u | u u | u u | u u | |
| Unloading....... | (A) | (a) | | | | | | | | u u | u u | u u | u u | u u | |
| Unloading....... | (B) | (b) | | | | | | | | u u | u u | u u | u u | u u | |

Five men and 4 horses put up 12.5 tons (10 acres) per day. Yield, 1.25 tons per acre. Man-hours 2.80, team-hours 1.62 per ton. Labor cost, $0.882 per ton.

### METHOD 15.

This method is used for making clover hay when it is desired to cure it quickly. The reason the cost is so high in this case is that the hay is tedded twice. The rake is not used and the loader takes up the hay from the swath. The one objection to this labor arrangement is that one man remains at the barn all of the time to mow away the hay. When hay is taken from the swath, the teams on wagon will require a driver. If E went to the field, it would allow two men to load and one to drive. Taking up hay from the swath entails less strenuous work in loading than does taking from windrow.

WORK CHART 15.—*Clover loaded with loader; unloaded with horse fork (Ohio).*

[This method is adapted to 60 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Mowing.......... | A | a | | | | | | | | | | | m m | m m | m m | |
| Mowing.......... | B | b | | | | | | | | | | | m m | m m | m m | |
| Tedding.......... | A | a | | | | t t | t t | t t | | t t | t t | t t | | | | |
| Hauling.......... | C | [1]cd | | | | | | | | h h | h h | h h | h h | h h | h h | |
| Loading.......... | D | | | | | | | | | l l | l l | l l | l l | l l | l l | |
| Unloading....... | E | (c or d) | | | | | | | | u u | u u | u u | u u | u u | u u | |
| Unloading....... | (CD) | | | | | | | | | u u | u u | u u | u u | u u | u u | |

[1] Four horses are used on wagon.

Five men and 8 horses put up 9 tons (6 acres) per day. Yield, 1.5 tons per acre. Man-hours 3.33, team-hours 3 per ton. Labor cost, per ton, $1.266.

### METHOD 16.

The tedder starts at 10 o'clock on hay cut the day before. This gives the first hay tedded three hours exposure to the sun. This method is in common use, although most farmers prefer to rake the hay without tedding, unless the yield is 2 tons or more per acre.

WORK CHART 16.—*Timothy and clover loaded with loader and unloaded with horse fork (Iowa).*

[This method is adapted to 100 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | | | | | | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | | | | | | |
| Tedding......... | C | c | | | | | t t | t t | | t t | t t | t t | t t | t t | |
| Hauling......... | A | a | | | | | | | | h h | h h | h h | h h | h h | |
| Hauling......... | B | b | | | | | | | | h h | h h | h h | h h | h h | |
| Loading......... | D | | | | | | | | | l l | l l | l l | l l | l l | |
| Unloading....... | E | | | | | | | | | u u | u u | u u | u u | u u | |
| Unloading....... | F | | | | | | | | | u u | u u | u u | u u | u u | |
| Unloading....... | (AB) | (a or b) | | | | | | | | u u | u u | u u | u u | u u | |

Six men and 6 horses put up 12.5 tons (10 acres) per day. Yield, 1.25 tons per acre. Man-hours 3.36, team-hours 2.16 per ton. Labor cost, per ton, $1.104.

### METHOD 17.

This method is in common use in southern Iowa, where timothy is headed for seed. After being headed, the stubble is cut for hay. The loader can be used to advantage, because the hay (or rather straw) is very light and only two men are needed on the wagon, one driving and the other building the load. If the field is much more than a quarter of a mile from the barn, a third team and wagon can be used to advantage, as two teams hauling will not keep the barn crew busy all of the time. By using three teams for hauling, the labor cost per ton should be lowered slightly.

WORK CHART 17.—*Headed timothy loaded with loader and unloaded with horse fork (Iowa).*

[This method is adapted to 140 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Mowing.......... | A | a | | | m m | m m | m m | m m | | m m | m m | m m | m m | m m | | |
| Raking[1].......... | B | b | | | r r | r r | r r | r r | | r r | r r | r r | r r | r r | | |
| Hauling......... | C | c | | | h h | h h | h h | h h | | h h | h h | h h | h h | h h | h h | |
| Hauling......... | D | d | | | h h | h h | h h | h h | | h h | h h | h h | h h | h h | h h | |
| Loading......... | E | | | | l l | l l | l l | l l | | l l | l l | l l | l l | l l | l l | |
| Unloading....... | F | e | | | u u | u u | u u | u u | | u u | u u | u u | u u | u u | u u | |
| Unloading....... | G | | | | u u | u u | u u | u u | | u u | u u | u u | u u | u u | u u | |
| Unloading....... | H | | | | u u | u u | u u | u u | | u u | u u | u u | u u | u u | u u | |

[1] Field raked twice.

Eight men and 10 horses put up 14 tons (14 acres) per day. Yield, 1 ton per acre. Man-hours 4.28, team-hours 2.80 per ton. Labor cost, per ton, $1.416.

## METHOD 18.

This method is given in order to show the advantage of using boys to fill out a crew. Two teams are used to haul from field. Two men build the load and one man sticks the fork at the barn. Thus, the third person on the wagon has nothing to do but drive. Boys can do this just as well as men, and they cost only half as much. With this method a crew of 7 men and 3 boys will put up hay for $1.02 per ton, while the cost of a crew of 10, all men, will increase the cost per ton by 12 cents, making the total cost $1.14 per ton. It is often possible to hire town boys for the easy work of driving the team on loads as well as for hoisting hay.

WORK CHART 18.—*Timothy and clover loaded with loader; unloaded with horse fork (Iowa).*

[This method is adapted to 125 acres.]

| Operation | Men | Teams | Time required |
|---|---|---|---|
| | | | 6 7 8 9 10 11 12 1 2 3 4 5 6 |
| Mowing.......... | A | a | m m m m m m m m    m m m m m m m m m m |
| Raking.......... | B | b | r r r r r r r r r r |
| Tedding......... | B | b | t t t t t t t t t t |
| Hauling......... | C | c | h h h h h h h h h h    h h h h h h h h h h |
| Hauling......... | D | d | h h h h h h h h h h    h h h h h h h h h h |
| Loading......... | E | | l l l l l l l l l l    l l l l l l l l l l |
| Loading......... | F | | l l l l l l l l l l    l l l l l l l l l l |
| Unloading....... | G | | u u u u u u u u u u    u u u u u u u u u u |
| Unloading....... | H | | u u u u u u u u u u    u u u u u u u u u u |
| Unloading....... | I | | u u u u u u u u u u    u u u u u u u u u u |
| Unloading....... | J | e | u u u u u u u u u u    u u u u u u u u u u |

Seven men, 3 boys, and 9 horses put up 25 tons (12.5 acres) per day. Yield, 2 tons per acre. Man-hours 3.66, horse-hours 3.50 per ton. Labor cost, $1.02 per ton. Three wagons are used in hauling with 2 boys driving. One boy drives team on hay rope.

### METHOD 19.

This crew is the same as No. 18 would be if composed entirely of men, except that an additional man and team work in the forenoon. With a yield of 2 tons per acre, but one mower mowing all day would be required, but with a yield of only 1.5 tons per acre it is necessary to use the second mower half a day in order to get enough hay (25 tons) cut to keep the hauling and barn crew busy. The use of 3 boys in place of men would reduce the cost 10 cents per ton.

WORK CHART 19.—*Timothy and clover loaded with loader; unloaded with horse fork (Iowa).*

[This method is adapted to 170 acres.]

| Operation | Men | Teams | Time required |
|---|---|---|---|
| | | | 6 7 8 9 10 11 12 1 2 3 4 5 6 |
| Mowing.......... | A | a | m m m m m m m m   m m m m m m m m m m |
| Mowing.......... | B | b | m m m m m m m m |
| Raking.......... | C | c | r r r r r r r r r r   r r r r r r r r r r |
| Hauling......... | D | d | h h h h h h h h h h   h h h h h h h h h h |
| Hauling......... | E | e | h h h h h h h h h h   h h h h h h h h h h |
| Loading......... | F | | l l l l l l l l l l   l l l l l l l l l l |
| Loading......... | G | | l l l l l l l l l l   l l l l l l l l l l |
| Unloading....... | H | [1]f | u u u u u u u u u u   u u u u u u u u u u |
| Unloading....... | I | | u u u u u u u u u u   u u u u u u u u u u |
| Unloading....... | J | | u u u u u u u u u u   u u u u u u u u u u |
| Unloading....... | K | | u u u u u u u u u u   u u u u u u u u u u |

[1] One horse used for unloading.

Eleven men and 11 horses put up 25.5 tons (17 acres) per day. Yield, 1.5 tons per acre. Man-hours 4.03, horse-hours 3.76 per ton. Labor cost, per ton, $1.18.

### METHOD 20.

This is a rather large crew, adapted to an area of 300 acres or more. The men are all employed throughout the day and there is no lost or idle time. Two teams and three wagons are used to haul in. As soon as a load arrives at barn, the team is hitched to an empty wagon, while the barn crew of 4 men unload. Two men remain in the field all of the time, to build load, so there is always one wagon loading, one being unloaded, and one on way between barn and field. This is a very efficient method.

WORK CHART 20.—*Timothy and clover loaded with loader; unloaded with horse fork (New York).*

[This method is adapted to 300 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Hauling......... | E | e | | h h | h h | h h | h h | h h | | h h | h h | h h | h h | h h | |
| Hauling......... | F | f | | h h | h h | h h | h h | h h | | h h | h h | h h | h h | h h | |
| Loading......... | G | | | l l | l l | l l | l l | l l | | l l | l l | l l | l l | l l | |
| Loading......... | H | | | l l | l l | l l | l l | l l | | l l | l l | l l | l l | l l | |
| Unloading....... | I | | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |
| Unloading....... | J | g | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |
| Unloading....... | K | | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |
| Unloading....... | L | | | u u | u u | u u | u u | u u | | u u | u u | u u | u u | u u | |

Twelve men and 14 horses put up 45 tons (30 acres) per day. Yield, 1.5 tons per acre. Man-hours 2.66, team-hours 1.55 per ton. Labor cost, $0.842 per ton.

## System 3.—Stacking With Push Rakes and Stacker.

The machinery used in making hay in the Middle Western States is very different from that used in the Eastern States. There are two reasons for this. First, a large percentage of the hay is stacked; second, horse labor is used as much as possible in order to reduce man labor, which is often hard to obtain. By using the push rake and stacker, the only hand labor needed is on the stack. (See figs. 7 and 8.)

Push rakes, also locally known as "sweeps," "runabouts," "bull rakes," and "go devils," differ considerably in details of construction. The capacity or amount of work done per day varies with the type of push rake, the skill of man and team operating it, yield per acre, etc. (See fig. 9.)

### METHOD 21.

This method compares very favorably with method No. 23, the difference being that it requires fewer men by one to stack almost as much hay as do the three men and one boy crew of No. 23. A boy could easily replace one of the men in this crew by raking in the forenoon and driving the team on the stacker in the afternoon. This method is in common use in the Middle West.

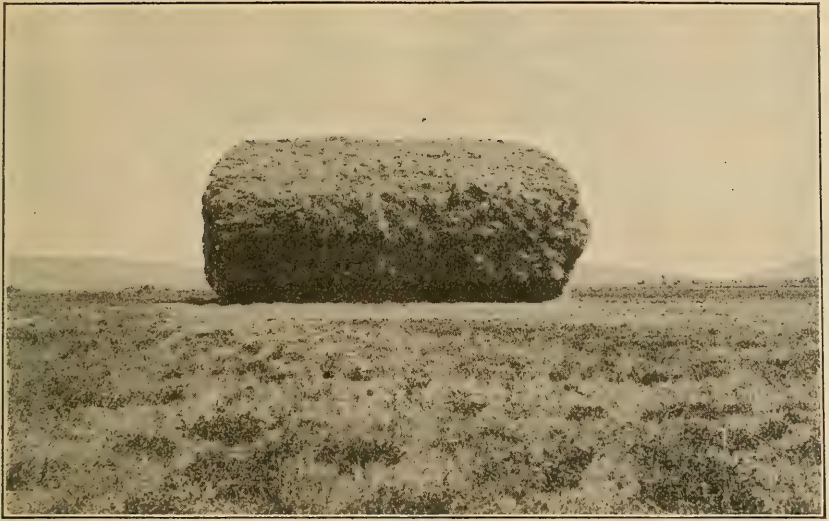

Fig. 7.—A well-built stack of western hay. Stacks like this lose a very small percentage of hay from damage by sun or rain.

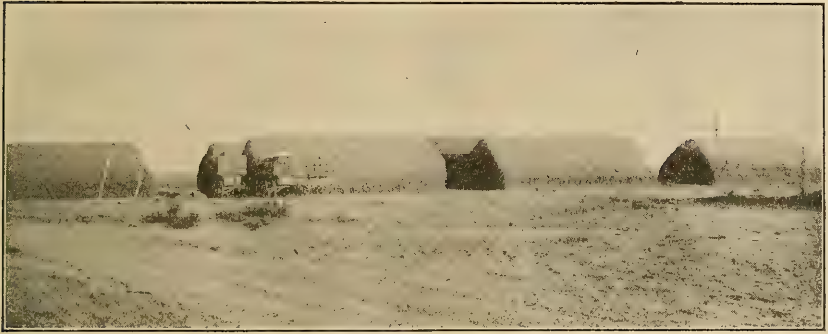

Fig. 8.—A group of well-built western stacks. Stacking such a large amount of hay in one place makes the cost of making hay very much greater than when the stacks are distributed over the field.

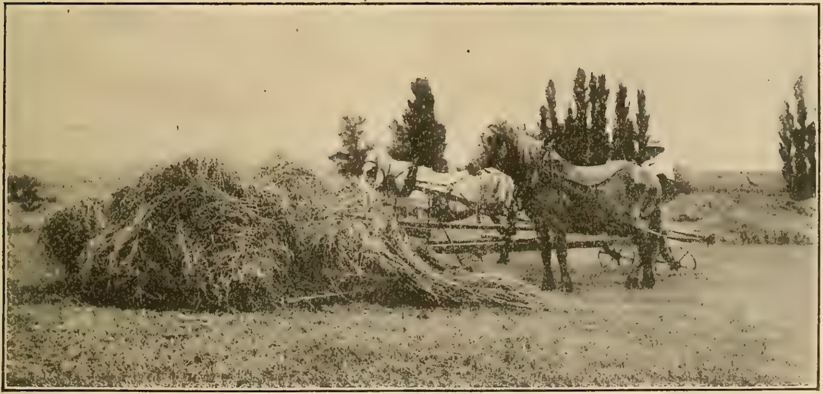

Fig. 9.—The push rake in operation. Horses do all of the labor of lifting the hay. From 600 to over 1,000 pounds of hay can be hauled per load. The skill of the driver and team are important factors in the efficient use of the push rake.

WORK CHART 21.—*Clover stacked with push rake and stacker (Nebraska).*

[This method is adapted to 60 acres.

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | | m | m m | m m | m m | | | | | | | |
| Mowing.......... | B | b | | | m | m m | m m | m m | | | | | | | |
| Raking.......... | C | c | | | r r | r r | r r | r r | | | | | | | |
| Push raking..... | A | | | | | | | | | p p | p p | p p | p p | p p | |
| Stacking........ | B | b | | | | | | | | s s | s s | s s | s s | s s | |
| Stacking........ | C | | | | | | | | | s s | s s | s s | s s | s s | |

Three men and 6 horses put up 9 tons (6 acres) per day. Yield, 1.5 tons per acre. Man-hours 2.88, team-hours 1.77 per ton. Labor cost, $0.93 per ton.

### METHOD 22.

This three-man crew arrangement is used on a sugar-beet farm in Kansas for a small acreage (not over 50 acres) where it is desired to allow all time possible for working in the beet field. Two men work the first day, one the second, and three the third day. By this method 32 acres, or 32 tons of hay, are harvested and put into the stack per week. The cost is considerably more than for method 24.

WORK CHART 22.—*Alfalfa stacked with push rakes and stacker (Kansas).*

[This method is adapted to about 50 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| First day: | | | | | | | | | | | | | | | |
| Mowing........ | A | a | | | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing........ | B | b | | | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Second day: | | | | | | | | | | | | | | | |
| Raking........ | A | a | | | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Third day: | | | | | | | | | | | | | | | |
| Push raking... | A | a | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking... | B | b | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking...... | C | c | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Three men and 6 horses put up 16 tons (16 acres) every three days, or an average of 5.33 tons per day. Yield, 1 ton per acre. Man-hours 3.50, team-hours 3.50 per ton. Labor cost, $1.40 per ton.

### METHOD 23.

This is a very good method for timothy and clover hay on areas up to 70 acres, especially where other farm work presses. It allows two of the crew to do other farm work in the forenoon. In the afternoon four men work all afternoon and stack 10.5 tons.

WORK CHART 23.—*Timothy and clover stacked with push rakes and stacker (Iowa).*

[This method is adapted to 70 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | | | m m | m m | m m | m | | | | | | |
| Mowing.......... | B | b | | | | m m | m m | m m | m | | | | | | |
| Raking.......... | A | a | | | | | | | | r | r r | r r | r r | | |
| Push raking..... | B | b | | | | | | | | p | p p | p p | p p | p p | p |
| Push raking..... | A | a | | | | | | | | | | | | p p | p |
| Stacking........ | C | | | | | | | | | s | s s | s s | s s | s s | s |
| Stacking........ | D | c | | | | | | | | s | s s | s s | s s | s s | s |

Three men, 1 boy, and 6 horses put up 10.5 tons (7 acres) per day. Yield, 1.5 tons per acre. Man-hours 2.33, team-hours 2.09 per ton. Labor cost, $0.884 per ton.

### METHOD 24.

This method is to be recommended in the West for a small acreage when there is considerable other work to be done. It can be used to advantage on a sugar-beet farm. Hay is only cut two days in the week, thus limiting the use of the method to about 100 acres of hay.

WORK CHART 24.—*Alfalfa stacked with push rakes and stacker (Kansas).*

[This method is adapted to about 100 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| First day: | | | | | | | | | | | | | | | |
| Mowing........ | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | | | |
| Mowing........ | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | | | |
| Mowing........ | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | | | |
| Raking........ | A | a | | | | | | | | | | | r r | r r | |
| Raking........ | B. | b | | | | | | | | | | | r r | r r | |
| Second day: | | | | | | | | | | | | | | | |
| Raking........ | A | a | | r r | r r | r r | r r | r r | | | | | | | |
| Raking........ | B | a | | r r | r r | r r | r r | r r | | | | | | | |
| Push raking... | A | a | | | | | | | | p p | p p | p p | p p | p p | |
| Push raking... | B | b | | | | | | | | p p | p p | p p | p p | p p | |
| Stacking...... | C | c | | | | | | | | s s | s s | s s | s s | s s | |
| Stacking...... | D | | | | | | | | | s s | s s | s s | s s | s s | |
| Third day: | | | | | | | | | | | | | | | |
| Push raking... | A | a | | p p | p p | p p | p p | p p | | | | | | | |
| Push raking... | B | b | | p p | p p | p p | p p | p p | | | | | | | |
| Stacking...... | C | c | | s s | s s | s s | s s | s s | | | | | | | |
| Stacking...... | D | | | s s | s s | s s | s s | s s | | | | | | | |

Four men and 6 horses put up 26 tons (26 acres) in 2.50 days. Yield, 1 ton per acre. Man-hours 3, team-hours 2.61 per ton. Labor cost, $1.12 yer ton.

## METHOD 25.

This method is used extensively in the prairie hay section of Oklahoma. It is not a very good one for the reason that only one sweep rake being used; the stacker is not kept very busy. Also, the rake is idle half of the day, and the stacker team and man driving it are idle over half of the time. If two mowers and two sweep rakes were used, the rake would be kept busy all day, and twice as much could be put into the stack without increasing the crew at the stack. Thus, the cost per ton would be lessened materially. (See method 31.)

WORK CHART 25.—*Prairie hay stacked with push rake and stacker (Oklahoma).*

[This crew can harvest 100 acres in 10 working days.]

| Operation | Men | Teams | Time required |
|---|---|---|---|
| | | | 6 7 8 9 10 11 12 1 2 3 4 5 6 |
| Mowing........ | A | a | m m m m m m m m m m m m m m m m m m m m |
| Raking.......... | B | b | r r r r r r r r r r |
| Push raking..... | C | c | p p p p p p p p p p p p p p p p p p p p |
| Stacking....... | D | d | s s s s s s s s s s s s s s s s s s s s |

Four men and 8 horses put up 10 tons or 10 acres per day. Yield, 1 ton per acre. Man-hours 3.50, team-hours 3.50 per ton. Labor cost, $1.40 per ton.

### METHOD 26.

This method does not require the use of a stacker. A few alfalfa growers in Kansas claim that it does not pay to buy a stacker to be used only 2 or 3 days at each cutting. The labor cost in this case is much higher than that for the average when a stacker is used, and the yield is but 1 ton per acre. If there is other farm work requiring 6 regular men, or if extra labor can be hired just when wanted, then it might be questionable if it would pay to buy a stacker. If help is scarce, however, 3 or 4 men, with 4 to 6 horses and a stacker, will put up as much hay as the 6 men and 4 horses, not using a stacker. (See fig. 10.)

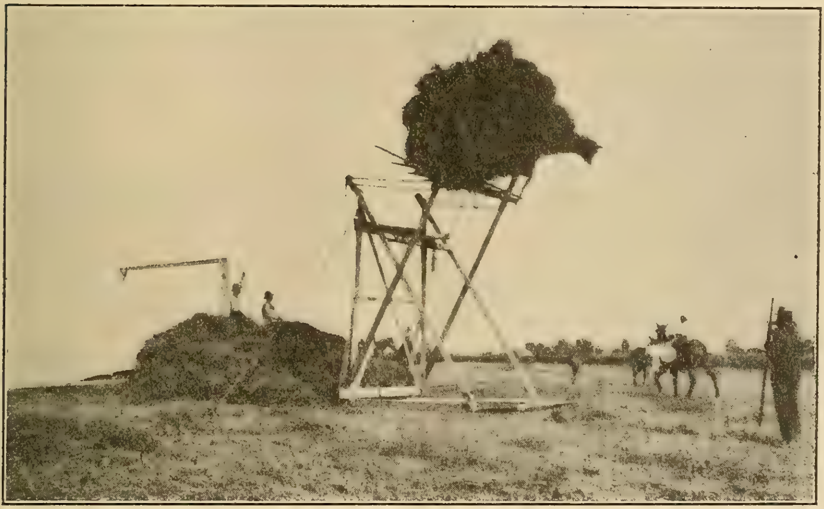

FIG. 10.—The haystacker in operation. The load is almost ready to be dumped on to the stack. No hard labor is required.

WORK CHART 26.—*Stacking alfalfa. Hay is brought to stack with push rake and pitched upon stack by hand.*

[This method is adapted to a small acreage, where it will not pay to buy a stacker.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | B | b | | | | | | | | r r | r r | r r | r r | r r | |
| Push raking..... | C | c | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | D | | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | E | | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | F | | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Six men and 6 horses put up 10 tons (10 acres) per day. Yield, 1 ton per acre. Man-hours 5.1, team-hours 1.92 per ton. Labor cost, $1.40 per ton.

## METHOD 27.

This method is well adapted to alfalfa on a farm growing sugar beets, or other crops that compete with hay in labor demands. Only one man works all forenoon. The second man starts raking at 10 o'clock, leaving 5 men free for other farm work. The amount handled per sweep in the afternoon (8 tons) indicates that the sweeps work fast and efficiently.

The only fault that could be found with this method lies in the long hours for the mower. This is necessary in order to keep the crew busy all afternoon.

WORK CHART 27.—*Irrigated alfalfa stacked with push rakes and stacker* (*Kansas*).

[This method is adapted to 160 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Mowing.......... | A | a | m m | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | m m | m | |
| Raking.......... | B | b | | | | | r r | r r | | r r | r r | r r | r r | r r | r r | | |
| Push raking..... | C | c | | | | | | | | p p | p p | p p | p p | p p | p p | | |
| Push raking..... | D | d | | | | | | | | p p | p p | p p | p p | p p | p p | | |
| Stacking........ | E | e | | | | | | | | s s | s s | s s | s s | s s | s s | | |
| Stacking........ | F | | | | | | | | | s s | s s | s s | s s | s s | s s | | |
| Stacking........ | G | | | | | | | | | s s | s s | s s | s s | s s | s s | | |

Seven men and 10 horses put up 16 tons (16 acres) per day. Yield, 1 ton per acre. Man-hours 3.15, team-hours 2.40 per ton. Labor cost, $1.10 per ton.

### METHOD 28.

This crew can handle as much as 250 acres of alfalfa per cutting. As it does not start to work until 8 o'clock, or when the dew is almost gone, it is necessary to use three 5-foot mowers to cut down 25 acres per day. Only one rake being used, there is no time for gleaning. One man on the stack has to take care of hay from two sweep rakes, and is worked rather hard, especially when the weather is very warm. This method is in common use in western Kansas.

WORK CHART 28.—*Alfalfa stacked with push rakes and stacker* (*Western Kansas*).

[This method is adapted to 250 acres.]

| Operation | Men | Teams | Time required |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a |  |  | m m | m m | m m | m m |  | m m | m m | m m | m m | m m |  |
| Mowing.......... | B | b |  |  | m m | m m | m m | m m |  | m m | m m | m m | m m | m m |  |
| Mowing.......... | C | c |  |  | m m | m m | m m | m m |  | m m | m m | m m | m m | m m |  |
| Raking.......... | D | d |  |  | r r | r r | r r | r r |  | r r | r r | r r | r r | r r |  |
| Push raking..... | E | e |  |  | p p | p p | p p | p p |  | p p | p p | p p | p p | p p |  |
| Push raking..... | F | f |  |  | p p | p p | p p | p p |  | p p | p p | p p | p p | p p |  |
| Stacking........ | G | g |  |  | s s | s s | s s | s s |  | s s | s s | s s | s s | s s |  |
| Stacking........ | H |  |  |  | s s | s s | s s | s s |  | s s | s s | s s | s s | s s |  |

Eight men and 14 horses put up 31.25 tons (25 acres) per day. Yield, 1.25 tons per acre. Man-hours 2.46, team-hours 2.14 per ton. Labor cost, $0.92 per ton.

### METHOD 29.

This crew arrangement is in common use in Colorado, where on account of there being no need to wait for dew to disappear, the crew starts at 7 a. m. The hay is raked with a side-delivery rake. Sometimes two men are used on the stack instead of one, as shown here.

WORK CHART 29.—*Irrigated alfalfa stacked with push rakes and stacker (Colorado).*

[This method is adapted to 300 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking | C | c | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking | D | d | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking | E | e | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking | G | g | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking | H | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Eight men and 14 horses put up 30 acres (30 tons) per day. Yield, 1 ton per acre. Man-hours 2.66, team-hours 2.33 per ton. Labor cost, $0.998 per ton.

## METHODS 30 AND 31.

Method 30 is given in order to show the high cost due to poor method. The hay is raked the second day with side-delivery rake. The third day two sweep rakes bring it from the windrow and dump it close to the stack site. The fourth day it is picked up by two other sweep rakes and stacked. Thus every day there are four sweeps in use, two dumping near the next stack site, and two picking up the bunches brought up the day before.

Method 31 is a rearrangement of method 30. The hay is delivered direct to stacker and not dumped on the ground. This reduces the crew from 9 men and 16 horses to 7 men and 12 horses, and lowers the cost 36 cents per ton.

WORK CHART 30.—*Irrigated alfalfa stacked with push rakes and stacker (Colorado).*

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing | A | a | | | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing | B | b | | | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking | C | c | | | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking | D | d | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking | E | e | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking | F | f | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking | G | g | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Staking | H | h | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking | I | | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Nine men and 16 horses put up 20 tons (20 acres) per day. Yield, 1 ton per acre. Man-hours 4.05, team-hours 3.60 per ton. Labor cost, $1.53 per ton.

WORK CHART 31.—*Irrigated alfalfa stacked with push rakes and stacker (Colorado).*

[This method is adapted to 200 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | C | c | | | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | D | d | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | E | e | | | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | F | f | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | G | | | | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Seven men and 12 horses put up 20 tons (20 acres) per day. Yield, 1 ton per acre. Man-hours 3.15, team-hours 2.70 per ton. Labor cost, $1.17 per ton.

### METHOD 32.

Method 32 is well adapted to an area of 300 acres of irrigated alfalfa. Three 5-foot mowers are used, each cutting 10 acres per day. The close spacing of irrigation ditches in some cases makes it necessary to use more mowers than in others. The sulky rake is used for gleaning, and the side-delivery rake for raking into the windrows.

WORK CHART 32.—*Irrigated alfalfa stacked with push rakes and stacker (Colorado).*

[This method is adapted to 300 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | E | e | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | G | g | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | [1] H | h | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | I | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | J | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Raking (gleaning)...... | K | 1 | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |

[1] Boy driving team on stacker.

Ten men, 1 boy, and 18 horses put up 37.5 tons (30 acres) per day. Yield, 1.25 tons per acre. Man-hours 2.80, team-hours 2.40 per ton. Labor cost, $1.04 per ton.

### METHOD 33.

This crew, used in Nebraska, makes more than 500 acres of prairie hay in a season. The yield being only 1 ton to the acre, it is necessary to use three mowers in order to cut sufficient hay to keep the stacking crew of two men busy. It is sometimes necessary to add two men to this crew, one to drive the team on the stacker and the other to help on the stack. Where large acreages are put up, it is the rule in some sections to have one man on the stack for every sweep rake, which increases somewhat the cost per ton.

WORK CHART 33.—*Prairie hay stacked with push rakes and stacker (Nebraska).*

[This method is adapted to over 500 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | m m | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | r r | |
| Raking.......... | E | e | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | r r | |
| Push raking..... | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | p p | |
| Push raking..... | G | g | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | p p | |
| Push raking..... | H | h | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | p p | |
| Stacking........ | I | i | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | s s | |
| Stacking........ | J | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | s s | |

Ten men and 18 horses put up 45 tons (45 acres) per day. Yield, 1 ton per acre. Man-hours 2.22, team-hours 2 per ton. Labor cost, $0.84 per ton.

### METHOD 34.

This method is adaptable to an area of 300 acres of timothy and clover. In order to cut 30 acres with two mowers in 10 hours, it is necessary to use 6-foot or 7-foot mowers when using the ordinary team. If 5-foot mowers are used, it will be necessary to use three of them, which will increase the cost per ton by about 8 cents. The rakes not only rake the 30 acres over once, but go over the windrows and glean the hay left by the sweep rake. (See No. 35, in which 3 mowers are used.) Twenty tons per sweep rake per day is a big day's work and represents about the maximum amount that can be handled even with a yield of 1⅓ tons per acre. Three sweeps usually are needed to handle 40 tons per day.

WORK CHART 34.—*Timothy and clover stacked with push rakes and stacker (Iowa).*

[This method is adapted to 300 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | C | c | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | E | e | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | G | g | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | H | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | I | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | J | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Ten men and 14 horses put up 40 tons (30 acres) per day. Yield per acre, 1.33 tons. Man-hours 2.50, team-hours 1.75 per ton. Labor cost, per ton, $0.85.

### METHOD 35.

This arrangement is the same as method 34, except that one more mower is used, the mower in this case being 5-foot instead of the 6-foot or 7-foot mower used in method 34.

WORK CHART 35.—*Timothy and clover stacked with push rake and stacker (Iowa).*

[This method is adapted to 300 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | E | e | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | G | g | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | H | h | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | I | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | J | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | K | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Eleven men and 16 horses put up 40 tons (30 acres) per day. Yield, 1.33 tons per acre. Man-hours 2.75, team-hours 2 per ton. Labor cost, $0.95 per ton.

### METHODS 36 AND 37.

Method 36 is used on a 100,000-acre ranch in Oklahoma, where 2,000 acres of prairie hay are made each year. The work chart is for but one of several crews used. The cost per ton is higher than the average, because with several units working there is no incentive for the men to "speed up." The average amount handled per sweep is less than 8 tons per day. Quite often, where a large number of men are working under a foreman, it will be found that the labor cost is higher than for a smaller crew, or a crew where the farmer himself works as one of the crew. (See fig. 11.)

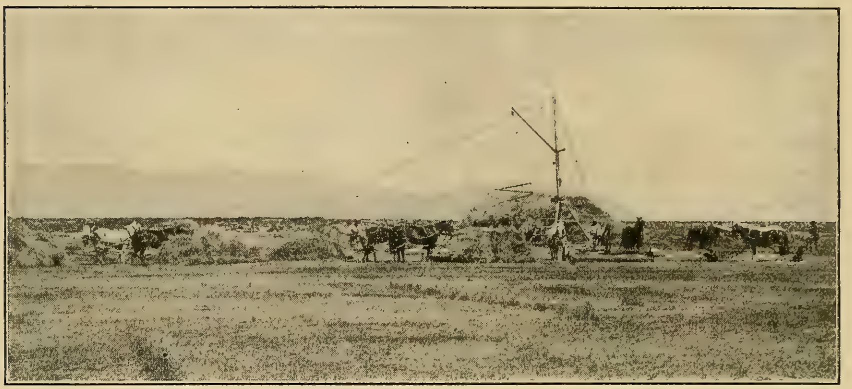

FIG. 11.—A large stacking crew at work in the West. Four push rakes (not all shown in the picture) are waiting to unload. The loss of time waiting to unload increases the cost of stacking. This loss of time can be avoided by proper management of the push-rake crew.

Method 37 is almost identical with method 36, having the same number of horses but one more man. This crew puts up 3 less tons per day than No. 36, and is not a fast-working crew

Work Chart 36.—*Prairie hay stacked with push rakes and stacker (Oklahoma).*

[This crew stacked about 1,000 acres per year.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | E | e | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | G | g | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | H | h | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | I | i | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | J | j | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | K | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | L | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | M | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Thirteen men and 20 horses put up 36 tons (36 acres) per day. Yield, 1 ton per acre. Man-hours 3.61, team-hours 2.77 per ton. Labor cost, $1.276 per ton.

Work Chart 37.—*Alfalfa stacked with push rakes and stacker (Oklahoma).*

[This method is adapted to 300 acres.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | E | e | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | G | g | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | H | h | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | I | i | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | J | j | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | K | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | L | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | M | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | N | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Fourteen men and 20 horses put up 33 tons (33 acres) per day. Yield, 1 ton per acre. Man-hours 4.16, team-hours 2.96 per ton. Labor cost, $1.424 per ton.

## METHOD 38.

This large crew is very efficient and makes over 1,000 acres of prairie hay each year. Each member of the crew puts in a full day every day. The cost per ton is low, because men and horses are well used to the work and there is no lost time. One more man is used on the stack than is customary when only three sweep rakes are used. This crew will put up 450 acres of tame hay in a 10-day season. The field is raked twice.

WORK CHART 38.—*Prairie hay stacked with push rakes and stacker (Nebraska).*

[This method is adapted to 1,000 acres or more of prairie hay or 450 acres of tame hay.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | E | e | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | F | f | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | G | g | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | H | h | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | I | i | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | J | j | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | K | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | L | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | M | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | N | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Fourteen men and 20 horses put up 67.5 tons (45 acres) per day. Yield, 1.5 tons per acre. Man-hours 2, team-hours 1.48 per ton. Labor cost, per ton, $0.696.

## METHOD 39.

The labor cost per ton for this method is high, $1.55 per ton. This is not due to poor crew management, but to the low yield per acre (only half a ton), necessitating twice the number of mowers and rakes to harvest a given amount of hay as would be required for a yield of 1 ton per acre. It will be noticed that while a sweep rake handled 12 tons per day, it must cover 24 acres to get this amount. To cover this area, a sweep must be kept on the jump every minute. This crew puts up 4,000 tons of prairie hay in Colorado.

WORK CHART 39.—*Prairie hay stacked with push rakes and stacker (Colorado).*

[This method is adapted to a large acreage.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | C | c | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | D | d | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | E | e | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | F | f | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | G | g | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | H | h | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | I | i | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | J | j | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | K | k | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | L | l | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Stacking........ | M | m | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | N | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |
| Stacking........ | O | | | s s | s s | s s | s s | s s | | s s | s s | s s | s s | s s | |

Fifteen men and 26 horses put up 36 tons (72 acres) per day. Yield, 0.5 ton per acre. Man-hours 4.16, team-hours 3.61 per ton. Labor cost, $1.55 per ton.

### System 4.—Baling from the Windrow.

The cheapest method of getting hay into the bale is to bale it directly from the windrow, using the sweep rake to bring it to the press. There is only one serious objection to this practice, and that is the danger of the hay not being dry enough to keep. This objection holds in the East and South, but not in the West.

In the prairie hay section of the Middle West it is customary to bale from the windrow, especially if the hay is to be shipped to market. The saving entailed by not stacking includes getting the hay upon the stack, stacking, and pitching from stack to the press. As the prairie haying season lasts for several weeks there, a small crew with a two-horse press will often bale over 600 tons per season. A power press will bale about twice as much as a horse press.

A two-horse press will bale from 6 to 15 tons of hay per day, the average probably being about 8 tons, although many crews will bale 10 tons per day.

The press crew requires from 3 to 5 men, and if the team requires it, a boy will be needed to drive. The crew ordinarily is arranged as follows: One or two pitchers, one pressman, one wirer, one driver (usually a boy). If a "patent" whip is used, the team on the press requires no driver. If the hay yields 1 ton per acre, one mower will be kept busy all day. One straight-tooth rake will be kept busy half a day, unless the operator rerakes, in which event it will be busy all day. One push rake will be required. With a yield of one-half ton per acre, two mowers will be required to cut enough down to keep the press busy, and the rake will only be able to rake the field over once.

When hay is baled in the field with a power press, the crew will vary from 8 to 16 or more men, and the number of horses used will be from 6 to 12 or more. Most power presses in the alfalfa and prairie hay regions are owned on farms having over 500 tons to bale per year, or by men who make custom baling their business. As a rule, a power press will bale from 500 to 3,000 tons per year, and in such cases the press and field crew get used to making and baling day after day and soon become proficient.

The seasonal repairs on power presses operated by inexperienced men may amount to several times as much as those on a press operated by skilled pressmen. The methods illustrated are those in common practice in the alfalfa and prairie hay sections.

### METHOD 40.

A common arrangement for small crews. This crew bales but 6 tons per day, the low output being largely due to the fact that only one horse is used on the press. One horse is not able to keep a press running at its maximum capacity all day. The hay field is raked twice, which also slightly increases the cost per ton.

WORK CHART 40.—*Prairie hay baled from the windrow with horse press.*

[This crew bales 90 tons per year.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | B | b | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | C | c | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Press crew: | | | | | | | | | | | | | | | |
| Pitching...... | D | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Feeding....... | E | | | f f | f f | f f | f f | f f | | f f | f f | f f | f f | f f | |
| Wiring........ | F | | | w w | w w | w w | w w | w w | | w w | w w | w w | w w | w w | |
| Driving....... | | d | | d d | d d | d d | d d | d d | | d d | d d | d d | d d | d d | |

Six men and 7 horses bale 6 tons (12 acres) per day. Yield, 0.50 ton per acre. Man-hours 10, horse-hours 11.66 per ton. Labor cost, $3.16 per ton. Cost of labor and wire, $3.41 per ton.

### METHOD 41.

This crew is composed of 6 men, only three men being used at the press—1 to feed, 1 to pitch, and 1 to wire the bales. The mower cuts 10 acres in 7½ hours. The pitcher works much harder than when 4 men are used at the press, and it is customary for the three men at the press to change places frequently to lighten the work on the pitcher. This crew will bale 600 tons of prairie hay per season.

WORK CHART 41.—*Prairie hay baled from the windrow with horse press (Oklahoma).*

[This crew bales 600 tons per year.]

| Operation | Men | Teams | Time required |
|---|---|---|---|
| | | | 6 7 8 9 10 11 12 1 2 3 4 5 6 |
| Mowing.......... | A | a | m m m m m    m m m m m m m m m m |
| Raking.......... | B | b | r r r r r r r r r r |
| Push raking..... | C | c | p p p p p p p p p p    p p p p p p p p p p |
| Press crew: | | | |
| Pitching...... | D | | p p p p p p p p p p    p p p p p p p p p p |
| Feeding....... | E | | f f f f f f f f f f    f f f f f f f f f f |
| Wiring........ | F | | w w w w w w w w w w    w w w w w w w w w w |
| Driving....... | | d | d d d d d d d d d d    d d d d d d d d d d |

Six men and 8 horses bale 10 tons (10 acres) per day. Yield, 1 ton per acre. Man-hours 6, team-hours 4 per ton. Labor cost, $2 per ton. Cost of labor and wire, $2.20 per ton.

### METHOD 42.

This method is used by a crew which makes a business of custom baling and works throughout the haying season pressing prairie hay. The mower is kept busy all day, and the sulky rake half a day. Four men work at the press, and with a yield of 1 ton per acre, 10 tons are baled each day. The rake team and driver are idle half a day, but can be used to help haul the baled hay to warehouse or car at shipping point.

This type of crew is very common in Oklahoma and other parts of the Middle West.

WORK CHART 42.—*Prairie hay baled from the windrow with horse press (Oklahoma).*

[This crew is operated by a man who makes a business of baling for others.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking | B | b | | | | | | | | r r | r r | r r | r r | r r | |
| Push raking | C | c | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Press crew: | | | | | | | | | | | | | | | |
| Pitching | D | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Feeding | E | | | f f | f f | f f | f f | f f | | f f | f f | f f | f f | f f | |
| Wiring | F | | | w w | w w | w w | w w | w w | | w w | w w | w w | w w | w w | |
| Driving | G | d | | d d | d d | d d | d d | d d | | d d | d d | d d | d d | d d | |

Seven men and 8 horses bale 10 tons (10 acres) per day. Yield, 1 ton per acre. Man-hours 6.50, team-hours 3.50 per ton. Labor cost, $2 per ton. Cost of labor and wire, $2.25 per ton.

### METHOD 43.

This method shows an arrangement of labor commonly used in the prairie-hay section of the Middle West. The size of the press crew is such that the men need not work overly hard. The 10 tons baled per day is a good day's work for a 2-horse press. The only objection to this method is that the rake is busy only half of the time. If the field were reraked, enough hay would be gleaned to more than pay for the labor cost of doing it.

WORK CHART 43.—*Prairie hay baled from the windrow with horse press.*

[This crew bales 320 tons per year.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking | B | b | | | | | | | | r r | r r | r r | r r | r r | |
| Push raking | C | c | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Press crew: | | | | | | | | | | | | | | | |
| Pitching | D | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching | E | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Feeding | F | | | f f | f f | f f | f f | f f | | f f | f f | f f | f f | f f | |
| Wiring | G | | | w w | w w | w w | w w | w w | | w w | w w | w w | w w | w w | |
| Driving | | d | | d d | d d | d d | d d | d d | | d d | d d | d d | d d | d d | |

Seven men and 8 horses bale 10 tons (10 acres) per day. Yield, 1 ton per acre. Man-hours 6.50, team-hours 3.50 per ton. Labor cost, $2 per ton. Cost of labor and wire, $2.25 per ton.

### METHOD 44.

This crew uses only three men at the press, the press team needing no driver. The yield being only one-half ton per acre, it is necessary to use two mowers and the sulky rake all day. This is a common arrangement in the prairie-hay sections of Oklahoma and Arkansas.

WORK CHART 44.—*Prairie hay baled from the windrow with horse press (Arkansas).*

| Operation | Men | Teams | Time required | |
|---|---|---|---|---|
| | | | 6 7 8 9 10 11 12 | 1 2 3 4 5 6 |
| Mowing.......... | A | a | m m m m m m m m m m | m m m m m m m m m m |
| Mowing.......... | B | b | m m m m m m m m m m | m m m m m m m m m m |
| Raking.......... | C | c | r r r r r r r r r r | r r r r r r r r r r |
| Push raking..... | D | d | p p p p p p p p p p | p p p p p p p p p p |
| Press crew: | | | | |
| Pitching...... | E | | p p p p p p p p p p | p p p p p p p p p p |
| Feeding....... | F | | f f f f f f f f f f | f f f f f f f f f f |
| Wiring........ | G | | w w w w w w w w w w | w w w w w w w w w w |
| Driving....... | | e | d d d d d d d d d d | d d d d d d d d d d |

Seven men and 10 horses bale 10 tons (20 acres) per day. Yield, 0.50 ton per acre. Man-hours 7, team-hours 5 per ton. Labor cost, $2.40 per ton. Cost of labor and wire, $2.65 per ton.

### METHOD 45.

This method is used in Oklahoma by a farmer who presses but 50 to 75 tons of hay per year. The daily output is a little below the average, and no doubt the slow performance of the crew is due to the fact that the men are not experienced haymakers and pressers, and that there is no incentive to "speed up," since the acreage is small.

WORK CHART 45.—*Prairie hay baled from the windrow with horse press (Oklahoma).*

[This crew bales 45 tons per year.]

| Operation | Men | Teams | Time required<br>6 7 8 9 10 11 12 1 2 3 4 5 6 |
|---|---|---|---|
| Mowing.......... | A | a | m m m m m m m m m m   m m m m m m m m |
| Raking.......... | B | b | r r r r r r r r r r (1 to 6) |
| Push raking..... | C | c | p p p p p p p p p p   p p p p p p p p p p |
| Press crew: | | | |
| Pitching...... | D | | p p p p p p p p p p   p p p p p p p p p p |
| Pitching...... | E | | p p p p p p p p p p   p p p p p p p p p p |
| Feeding....... | F | | f f f f f f f f f f   f f f f f f f f f f |
| Wiring........ | G | | w w w w w w w w w w   w w w w w w w w w w |
| Driving....... | H | d | d d d d d d d d d d   d d d d d d d d d d |

Eight men and 8 horses bale 7.50 tons (6 acres) per day. Yield, 1.25 tons per acre. Man-hours 9.73, team-hours 4.40 per ton. Labor cost, per ton, $2.82. Cost of labor and wire, $3.07 per ton.

METHOD 46.

Work chart 46 shows the labor distribution of a crew used for custom-baling in Oklahoma. Very often it will be found that crews making a business of baling hay throughout the season include one more man than in the case of the owner who bales only his own hay, or, at most, a small quantity. The added cost over that of method 44 is caused by the extra man in the press crew. (See fig. 12.)

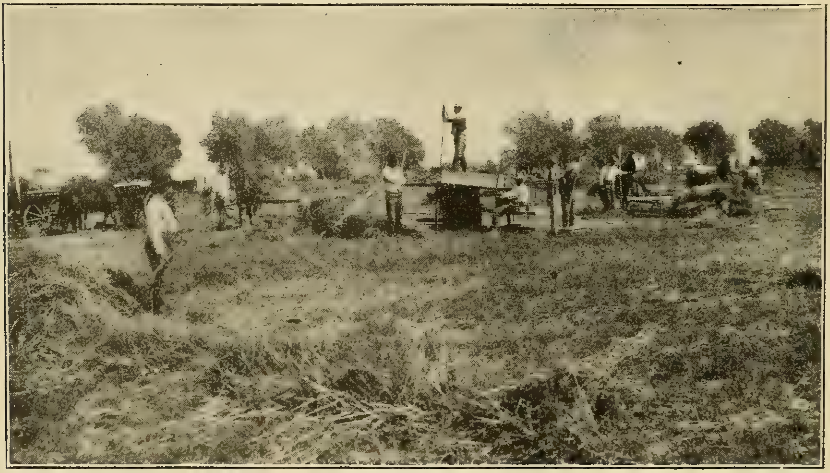

FIG. 12.—Baling alfalfa, cured in the cock, with a two-horse press. More men are used in the baling crew than is necessary. Large press crews make the work per man easy, but increases greatly the cost per ton of baling.

WORK CHART 46.—*Prairie hay baled from the windrow with horse press (Oklahoma).*

[This crew is operated by a custom baler.]

| Operation | Men | Teams | Time required: 6 7 8 9 10 11 12 1 2 3 4 5 6 |
|---|---|---|---|
| Mowing.......... | A | a | m m m m m m m m m m    m m m m m m m m m m |
| Mowing.......... | B | b | m m m m m m m m m m    m m m m m m m m m m |
| Raking.......... | C | c | r r r r r r r r r r    r r r r r r r r r r |
| Push raking..... | D | d | p p p p p p p p p p    p p p p p p p p p p |
| Press crew: | | | |
| Pitching...... | E | | p p p p p p p p p p    p p p p p p p p p p |
| Feeding....... | F | | f f f f f f f f f f    f f f f f f f f f f |
| Wiring........ | G | | w w w w w w w w w w    w w w w w w w w w w |
| Driving....... | H | e | d d d d d d d d d d    d d d d d d d d d d |

Eight men and 10 horses bale 10 tons (20 acres) per day. Yield, 0.50 ton per acre. Man-hours 8, team-hours 5 per ton. Labor cost, $2.60 per ton. Cost of labor and wire, $2.85 per ton.

### METHOD 47.

This crew, with a yield of 1½ tons of Johnson grass hay per acre, will bale 15 tons of hay per day of 11 hours, if a good day's run is made. This record is high for a crew of this size, but with a "three-stroke" press and everybody working hard, it is possible to bale out 15 tons. It is customary, with this output, to change teams on the press. A driver, a boy, handles the press team, which insures keeping the press going at its maximum speed.

WORK CHART 47.—*Johnson grass baled from the windrow with horse press (Texas).*

| Operation | Men | Teams | Time required: 6 7 8 9 10 11 12 1 2 3 4 5 6 7 |
|---|---|---|---|
| Mowing.......... | A | a | m m m m m m m m m m    m m m m m m m m m m m m |
| Raking.......... | B | b | r r r r r r r r r r    r r r r r r r r r r r r |
| Push raking..... | C | c | p p p p p p p p p p    p p p p p p p p p p p p |
| Press crew: | | | |
| Pitching...... | D | | p p p p p p p p p p    p p p p p p p p p p p p |
| Pitching...... | E | | p p p p p p p p p p    p p p p p p p p p p p p |
| Feeding....... | F | | f f f f f f f f f f    f f f f f f f f f f f f |
| Wiring........ | G | | w w w w w w w w w w    w w w w w w w w w w w w |
| Driving....... | H | d | d d d d d d d d d d    d d d d d d d d d d d d |

Seven men, 1 boy, and 8 horses bale 15 tons (12 acres) per day. Yield, 1.25 tons per acre. Man-hours 5.50, team-hours 2.93 per ton. Labor cost, $1.68 per ton. Labor cost and wire, $1.93 per ton.

### METHOD 48.

This method shows a distribution of labor not often found. The greatest fault of this plan is the long hours worked by the mower. Thirteen hours makes a very long day for man or team. By using a different team in the afternoon, it is possible to cut 16 acres per day. Method 49 is a better arrangement with regard both to hours worked and to labor cost per ton.

WORK CHART 48.—*Prairie hay baled from the windrow with gasoline power press (Oklahoma).*

[This crew bales 300 tons per year.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Mowing.......... | A | a | m m | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | m m | m m | |
| Raking.......... | B | b | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | | | |
| Push raking..... | C | c | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | p p | | |
| Press crew: | | | | | | | | | | | | | | | | | |
| Pitching...... | D | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | p p | | |
| Pitching...... | E | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | p p | | |
| Feeding....... | F | | | f f | f f | f f | f f | f f | | f f | f f | f f | f f | f f | f f | | |
| Wiring........ | G | | | w w | w w | w w | w w | w w | | w w | w w | w w | w w | w w | w w | | |
| Wiring........ | H | | | w w | w w | w w | w w | w w | | w w | w w | w w | w w | w w | w w | | |

Eight men and 6 horses bale 16 tons (16 acres) per day. Yield, 1 ton per acre. Man-hours 5.60, team-hours 2.13 per ton. Labor cost, $1.54 per ton. Cost of labor, gasoline, and wire, $1.94 per ton.

### METHOD 49.

This method is almost identical with method 50. The only difference is that the rake starts 2 hours later than in the other method. Both methods are in common use in the prairie-hay section of the Middle West.

WORK CHART 49.—*Prairie hay baled from the windrow with gasoline power press (Oklahoma).*

| Operation | Men | Teams | Time required | |
|---|---|---|---|---|
| | | | 6 7 8 9 10 11 12 | 1 2 3 4 5 6 |
| Mowing.......... | A | a | m m m m m m m m m m | m m m m m m m m m m |
| Mowing.......... | B | b | m m m m m m m m m m | m m m m m m m m m m |
| Raking.......... | C | c | r r r r r r | r r r r r r r r r r |
| Push raking..... | D | d | p p p p p p p p p p | p p p p p p p p p p |
| Press crew: | | | | |
| Pitching...... | E | | p p p p p p p p p p | p p p p p p p p p p |
| Pitching...... | F | | p p p p p p p p p p | p p p p p p p p p p |
| Feeding....... | G | | f f f f f f f f f f | f f f f f f f f f f |
| Wiring........ | H | | w w w w w w w w w w | w w w w w w w w w w |

Eight men and 8 horses bale 18 tons (18 acres) per day. Yield, 1 ton per acre. Man-hours 4.60, team-hours 2.19 per ton. Labor cost, $1.36 per ton. Cost of labor, gasoline, and wire, $1.75 per ton.

## METHOD 50.

This method shows the smallest possible crew for the operation of a power press baling 20 tons per day. This crew bales more than 1,000 tons of prairie hay per season. There is no lost or idle time. The crew works 11 hours per day. With this method, 5 men instead of 4 are used very often on the press crew, in order to make the work a little easier.

WORK CHART 50.—*Prairie hay baled from the windrow with gasoline power press (Kansas).*

[This crew bales over 1,000 tons per year.]

| Operation | Men | Teams | Time required | |
|---|---|---|---|---|
| | | | 6 7 8 9 10 11 12 | 1 2 3 4 5 6 7 |
| Mowing.......... | A | a | m m m m m m m m m m | m m m m m m m m m m m m |
| Mowing.......... | B | b | m m m m m m m m m m | m m m m m m m m m m m m |
| Raking.......... | C | c | r r r r r r r r r r | r r r r r r r r r r r r |
| Push raking..... | D | d | p p p p p p p p p p | p p p p p p p p p p p p |
| Press crew: | | | | |
| Pitching...... | E | | p p p p p p p p p p | p p p p p p p p p p p p |
| Pitching...... | F | | p p p p p p p p p p | p p p p p p p p p p p p |
| Feeding....... | G | | f f f f f f f f f f | f f f f f f f f f f f f |
| Wiring........ | H | | w w w w w w w w w w | w w w w w w w w w w w w |

Eight men and 8 horses bale 20 tons (20 acres) per day. Yield, 1 ton per acre. Man-hours 4.40, team-hours 2.20 per ton. Labor cost, $1.32 per ton. Cost of labor, gasoline, and wire, $1.69 per ton.

### METHOD 51.

This crew bales 5 tons more per day than the crew used in method 50. Twenty tons per day is about all a sweep rake will handle. In order to bale 5 more tons, it is necessary to use 2 sweep rakes and more men at the press. The press crew is kept very busy, but is not overworked, as a 4-man press crew would be. In this crew there is 1 engineer, 1 feeder, 2 pitchers, 2 wiremen, and 1 man to haul water and help about the press. This crew bales 1,800 tons per season.

WORK CHART 51.—*Prairie hay baled from the windrow with steam press.*

[This crew bales 1,800 tons per year.]

| Operation | Men | Teams | Time required |
|---|---|---|---|
| | | | 6 7 8 9 10 11 12 1 2 3 4 5 6 |
| Mowing.......... | A | a | m m m m m m m m m m  m m m m m m m m m m |
| Mowing.......... | B | b | m m m m m m m m m m  m m m m m m m m m m |
| Raking.......... | C | c | r r r r r r r r r r  r r r r r r r r r r |
| Push raking..... | D | d | p p p p p p p p p p  p p p p p p p p p p |
| Push raking..... | E | e | p p p p p p p p p p  p p p p p p p p p p |
| Press crew: | | | |
| Pitching...... | F | | p p p p p p p p p p  p p p p p p p p p p |
| Pitching...... | G | | p p p p p p p p p p  p p p p p p p p p p |
| Feeding....... | H | | f f f f f f f f f f  f f f f f f f f f f |
| Wiring........ | I | | w w w w w w w w w w  w w w w w w w w w w |
| Wiring........ | J | | w w w w w w w w w w  w w w w w w w w w w |
| Engineer...... | K | | e e e e e e e e e e  e e e e e e e e e e |
| Hauling water. | L | f | h h h h h h h h h h  h h h h h h h h h h |

Twelve men and 12 horses bale 25 tons (25 acres) per day. Yield, 1 ton per acre. Man-hours 4.80, team-hours 2.40 per ton. Labor cost, $1.44 per ton. Total cost, including wire, $1.69 per ton.

### METHOD 52.

This crew is used on an Oklahoma farm producing 450 acres of alfalfa. It will be necessary to use two 8-foot mowers to cut 35 acres per day. If 6-foot mowers are used, three will be required, which will increase the cost about 15 cents per ton. The two 11-foot side-delivery rakes not only rake 35 acres per day, but turn the windrows over the second day. The press crew is necessarily fairly large on account of the hay being heavy to handle and the weather hot. As no hay is bunched or cocked, the crew will lose some time mornings if there is a heavy dew.

WORK CHART 52.—*Alfalfa baled from the windrow with gasoline power press (Oklahoma).*

[This crew bales the hay from 450 acres per year.]

| Operation | Men | Teams | Time required | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| Mowing.......... | A | a | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Mowing.......... | B | b | | m m | m m | m m | m m | m m | | m m | m m | m m | m m | m m | |
| Raking.......... | C | c | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Raking.......... | D | d | | r r | r r | r r | r r | r r | | r r | r r | r r | r r | r r | |
| Push raking..... | E | e | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Push raking..... | F | f | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Press crew: | | | | | | | | | | | | | | | |
| Pitching...... | G | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching...... | H | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Pitching...... | I | | | p p | p p | p p | p p | p p | | p p | p p | p p | p p | p p | |
| Feeding....... | J | | | f f | f f | f f | f f | f f | | f f | f f | f f | f f | f f | |
| Wiring........ | K | | | w w | w w | w w | w w | w w | | w w | w w | w w | w w | w w | |
| Wiring........ | L | | | w w | w w | w w | w w | w w | | w w | w w | w w | w w | w w | |
| Bearing away bales....... | M | | | b b | b b | b b | b b | b b | | b b | b b | b b | b b | b b | |

Thirteen men and 12 horses bale 20 tons (35 acres) per day. Yield, 0.57 tons per acre. Man-hours 6.50, team-hours 3 per ton. Labor cost, $1.90 per ton. Cost of labor, gasoline, and wire (3 wires to the bale), $2.38 per ton.

### METHOD 53.

This crew appears to compare unfavorably with others shown, judging by the relatively high cost per ton. The main reason for this higher cost is that the temperature is very high, making it necessary to have almost a double press crew. There are 2 feeders and 4 pitchers. These are divided into two crews and work in 20-minute shifts. One man is kept busy all day bunching or cocking with a hand fork, so that hay will be ready to bale in the early morning before the dew is off of the hay in the swath and windrow. (See fig. 13.)

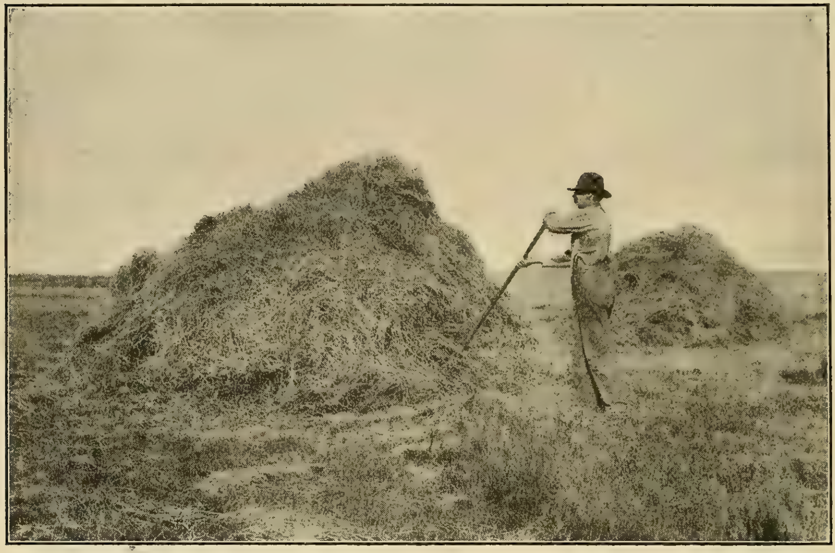

FIG. 13.—Bunching hay. The hay has been put into piles with a push rake. A hand fork is used to "round up" the piles. Enough hay is bunched every day to keep the baler busy in the morning until the dew is off the hay in the windrow. This practice enables the press crew to do a full day's work.

WORK CHART 53.—*Prarie hay baled from the windrow with gasoline power press (Oklahoma).*

[This crew bales over 2,000 tons per year.]

| Operation | Men | Teams | Time required |
|---|---|---|---|
| | | | 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 |
| Mowing.......... | A | a | m m m m m m m m m m m m m    m m m m m m m m m m m m m |
| Mowing.......... | B | b | m m m m m m m m m m m m m    m m m m m m m m m m m m m |
| Raking.......... | C | c | r r r r r r r r r r r r r    r r r r r r r r r r r r r |
| Raking.......... | D | d | r r r r r r r r r r r r r    r r r r r r r r r r r r r |
| Push raking..... | E | e | p p p p p p p p p p p p p    p p p p p p p p p p p p p |
| Push raking..... | F | f | p p p p p p p p p p p p p    p p p p p p p p p p p p p |
| Bunching........ | G | | b b b b b b b b b b b b b    b b b b b b b b b b b b b |
| Press crew: | | | |
| Pitching...... | H | | p p p p p p p p p p p p p    p p p p p p p p p p p p p |
| Pitching...... | I | | p p p p p p p p p p p p p    p p p p p p p p p p p p p |
| Pitching...... | J | | p p p p p p p p p p p p p    p p p p p p p p p p p p p |
| Pitching...... | K | | p p p p p p p p p p p p p    p p p p p p p p p p p p p |
| Feeding....... | L | | f f f f f f f f f f f f f    f f f f f f f f f f f f f |
| Feeding....... | M | | f f f f f f f f f f f f f    f f f f f f f f f f f f f |
| Wiring........ | N | | w w w w w w w w w w w w w    w w w w w w w w w w w w w |
| Wiring........ | O | | w w w w w w w w w w w w w    w w w w w w w w w w w w w |
| Bearing away bales....... | P | | b b b b b b b b b b b b b    b b b b b b b b b b b b b |
| Foreman[1]...... | Q | | f f f f f f f f f f f f f    f f f f f f f f f f f f f |

[1] Helps feed, pitch, or do any other necessary work.

Seventeen men and 12 horses bale 35 tons (28 acres) per day. Man-hours 6.31, team-hours 2.22 per ton Labor cost, $1.70 per ton. Cost of labor, gasoline, and wire, $2.07 per ton.

## CONCLUSION.

This study emphasizes the fact that many farmers make hay in a haphazard fashion, without any definite method adapted to individual conditions. This is especially true of the farmers of the East, where comparatively small acreages of hay are grown. In the States where large acreages are handled, necessity has brought home to the farmers the fact that failure to adopt a method suited to the crew available and to the acreage to be harvested may result in poor hay and an excessive labor cost. Hence, as a rule, it was found that the more efficient methods of handling hay were in vogue in the middle and western States.

It was found that small crews often were more efficient than very large ones. This was especially noticeable where the push rake was used. Five push rakes often will put into the stack as much hay as seven, since the latter, where the haul is short, will bring the hay in faster than it can be stacked.

Baling hay from the field was found to be the cheapest system of putting hay into the bale. It should be noted, however, that this system usually can be used to advantage only in regions where little or no rain falls during the haying season. Bunching enough hay in the afternoon to keep the baler busy an hour or two in the morning is a common practice among the more efficient crews studied. This obviates loss of time in the morning while the dew is drying from the hay in the swath or windrow. The total day's output of the baler often was found to be limited by the capacity of the mower rather than by that of the press. In the best practice care is taken to provide means for cutting enough hay to keep the presses running at full capacity.

Two reasons why the hay loader is not in more general use were given by the farmers visited, namely, the relatively large cash outlay entailed and the fact that handling hay on the wagon with a loader is very heavy work as compared with driving a push rake.

The detailed methods illustrated here are given merely as a basis of study, to help the hay grower in working out the method best adapted to his own conditions. The costs per ton for man and for horse labor are only relative, and while in the main perhaps approximately correct, at least as regards man labor, they are not intended to represent the actual cost of making hay in the several localities visited.

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# CELERY STORAGE EXPERIMENTS.[1]

By H. C. THOMPSON,

*Horticulturist, Office of Horticultural and Pomological Investigations.*

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## INTRODUCTION.

Celery is one of the important truck crops grown in the United States. The farm value of the crop of 1909 was $3,922,848, of which crop eight States, New York, Michigan, Florida, California, Massachusetts, Ohio, Pennsylvania, and New Jersey, produced about 86 per cent. The six northern States mentioned produce about two-thirds of the celery grown in the United States, and as a considerable portion of this is stored for a period of one to three months the merchan-

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[1] The writer wishes to acknowledge his indebtedness to Mr. C. C. Locke, of Arkport, N. Y., Mr. Henry Greffrath, South Lima, N. Y., and Mr. W. P. Rodgers, Williamson, N. Y., for their courtesy in allowing him to select from their fields the celery used in these experiments; also to the managers of the Hygeia Refrigerating Co., Elmira, N. Y., the Hornell Ice & Storage Co., Hornell, N. Y., and the Williamson Ice & Storage Co., Williamson, N. Y., in whose houses the experimental lots of celery were stored, for valuable assistance rendered.

NOTE.—The fruit and vegetable handling, transportation, and storage investigations formerly administered in the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry are now being prosecuted jointly and cooperatively by the Bureau of Plant Industry and the Bureau of Markets.

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dising value of the crop is much greater than the farm value given in the above figures. With better methods of storage the value would be still further increased.

To hold celery in cold-storage warehouses is a comparatively new undertaking, and for this reason very little definite information is available on the subject. Storing celery in pits in the field and in common storages of the cellar type has been practiced for a long time, but these methods are not satisfactory because the temperature and moisture conditions can not be controlled.

During some seasons celery banked in the field keeps in good condition for several months, while during other seasons the crop decays in a short time. When the weather is warm and moist during the storage period, celery in banks or pits usually decays. Sometimes the crop is considerably injured by freezing. Even if celery could be stored in pits in the field with very little loss, the method would not be entirely satisfactory, because conditions are not always favorable for its removal when wanted for market. The greatest market demand often occurs during a rainy period or during very cold weather when it is difficult to remove celery from banks or pits.

As celery is quite perishable, often decaying in a very short time, most storage-house managers prefer to handle other products. For this reason it is becoming very difficult for celery growers and dealers to secure storage space for their product. If it could be shown that celery which reaches the storage house in good condition can be held in a satisfactory condition under refrigeration for a period of three months or more, there would be less difficulty in securing storage space for celery. It is believed that the data presented in this bulletin prove that celery can be held in good condition for that length of time. In every instance where the celery showed considerable decay under three months the conditions in the storage room were not good. In most cases, however, the experimental lots of celery kept in good condition until the room was nearly empty, when the room temperature for a few days was not properly regulated. It should be added, however, that celery which reaches the storage house very badly diseased or in a heated condition will not keep as long as that which reaches the house in good condition. The management should not be held responsible for loss due to poor methods of handling before the celery reaches the storage house.

A clear knowledge of the factors which cause or hasten the decay of celery in storage and the methods that can be employed to lessen this loss is essential to successful celery storage. As has been stated, if storage-house managers know that celery which reaches the storage house in good condition can be held for a period of three months with very little loss, they will more readily accept celery for storage. Also, if growers and dealers realize that for satisfactory results celery must be properly handled before it reaches the storage house, they will use more care in preparing the crop for storing.

## PRELIMINARY STUDY.

Before starting the investigational work, which was continued for a period of four years, a preliminary study of the conditions prevailing in storage houses and on the market was made. It was observed that celery held for two or three months nearly always showed some decay and that this decay developed faster in the center than in outer parts of the crate. In many instances the stored celery was so badly decayed that the tops had the appearance of being scooped out in the center of the crate.

It was also observed that the large crates were often so badly broken when they reached the market that the celery was considerably injured, and in many cases the crates had to be repaired or entirely remade. The crates when filled with celery were so heavy that they were broken in ordinary handling, especially in loading in the field and in loading and unloading at the storage house and at the market.

Under ordinary conditions the celery is loaded on a wagon in the field and unloaded from the wagon into cars for shipment to the storage house. At the storage house it is taken from the car, placed on hand trucks, and transferred to the storage room, where it is unloaded and piled four, five, or six crates high. When the celery is ready for shipment to market it is again transferred on hand trucks and loaded into cars. At the market center it is loaded into wagons or motor trucks and hauled to and unloaded at the wash rooms. Sometimes the crated celery is handled two or three times more before it reaches the retailer. With this amount of handling it can be readily seen that the crates would have to be very strongly made to prevent breakage. When the crates are badly broken, the celery stalks are often crushed and the injured portions offer entrance for decay-producing organisms.

## OBJECTS AND OUTLINE OF THE EXPERIMENTS.

The main objects of the experimental work were as follows:

(1) To determine the factors which hasten decay in celery in storage houses.

(2) To determine the best method or methods of reducing the loss of celery in storage due to decay and mechanical injury.

(3) To determine the best type of crate in which to pack celery to be held in a cold-storage warehouse.

(4) To study the effect of the temperature of the storage room on the keeping quality of celery.

The celery used in the experiments during the four years was grown and stored in western New York. Each experimental lot was packed in the field and graded in the storage house by representatives of the Department of Agriculture. In every instance the celery used was free from disease and was so handled that the different lots were comparable. Each year's results are given separately, as the length of the storage period was not the same and the celery was not stored in the same house every year.

The crates used in the experiments were as follows:

(1) The standard crate, which ranges in size from 22 by 22 to 24 by 24 inches, although generally measuring 22 by 23 or 23 by 24 inches.

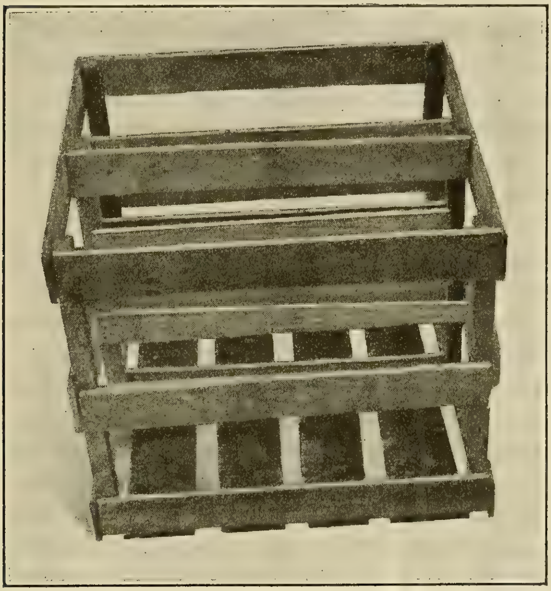
(2) The partition-ventilated crate, which is the standard crate with a ventilated partition through the center, as shown in figures 1 and 2. This partition is made by nailing three or four slats on each side of 1 or 1¼ inch posts. The slats and posts are the same size as those used for the sides and ends of the crates.

(3) The 16-inch crate, 16 inches wide and the same length and depth as the standard crate.

(4) The 14-inch crate, 14 inches wide and the same length and depth as the standard crate.

(5) The 10-inch crate, 10 inches wide and the same length and depth as the standard crate.

(6) The 11-inch solid-head crate, 11 inches wide, 24 inches long, and 24 inches deep.



P1859HP

FIG. 1.—Partition crate used in the celery storage experiments.

In 1912–13 the standard, the partition-ventilated, and the 10-inch crates were used. In 1913–14, 1914–15, and 1915–16 the standard and partition-ventilated crates were used, but the 10-inch crate was discarded after the first year, because it was too small for practical purposes. Each year after 1912–13 the 14-inch and the 16-inch crates were used.

Figure 3 shows a 14-inch, a 16-inch, and a partition-ventilated crate filled with celery. The 11-inch solid-head crate was used at Williamson in 1914–15 and at Williamson and Hornell in 1915–16. In every case where the partition crate is mentioned, the reference is to the standard crate with the ventilated partition in the center.

## EXPERIMENTS IN 1912–13.

The celery used in the experiment in 1912–13 was grown at Arkport and stored at Elmira, N. Y. The experimental lots were harvested in the afternoon of October 18, 1912, and shipped the same day by express to Elmira. The following morning they were unloaded and stacked in the storage house. The crates were piled five high, with a 2-inch scantling between the crates and a 2 to 3 inch air space between the stacks. The celery was examined three times while in storage, and at the third examination, February 13, 1913, it was graded. The results of this grading are shown in Table I.

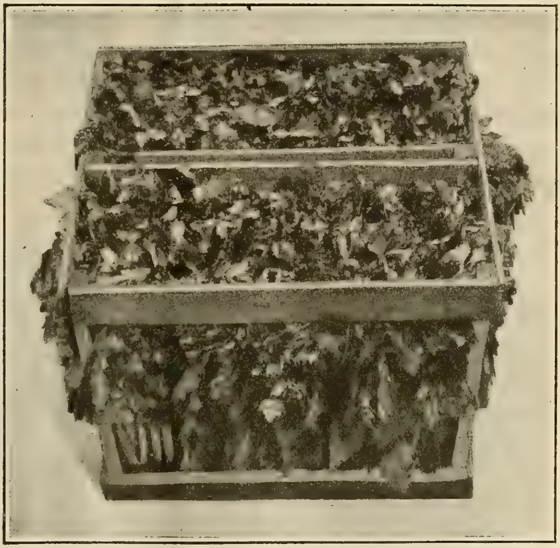

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FIG. 2.—Partition crate filled with celery. Note the air space, which extends to the bottom of the crate.

The sound celery was free from disease, or so slightly diseased that very few of the leaves had to be stripped off in preparing it for market. The slightly decayed celery consisted of stalks which were diseased and required so much stripping that the bunches were small and contained little foliage. The ordinary ratio of the price of these two grades would be about 5 to 3. In other words, if a bunch of 12 stalks of sound celery sells for 50 cents, a bunch of slightly decayed celery would sell for about 30 cents.

TABLE I.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Elmira, N. Y., when inspected on February 13, 1913.*

| Type of crate. | Total number of stalks. | Sound. | | Slightly decayed. | |
|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. |
| Standard | 430 | 305 | 70.9 | 125 | 29.1 |
| Partition | 416 | 395 | 94.95 | 21 | 5.05 |
| 10-inch | 200 | 194 | 97.0 | 6 | 3.0 |

Table I shows that the partition crate contained 24 per cent and the 10-inch crate about 26 per cent more sound celery than the standard crate. The difference in the amount of decay in different parts of the standard crate was very noticeable, while in the other crates there was very little difference.

## EXPERIMENTS IN 1913–14.

The celery used in the experiment in 1913–14 was grown at South Lima and stored at Elmira, N. Y. It was harvested October 29, 1913, loaded into a box car the same day, and shipped to Elmira, where it was unloaded and put in storage the following morning. The weather was cold when this celery was harvested, and it reached the storage house in good condition. The crates, 10 in each lot, were piled in the house in the same way as those stored in 1912–13.

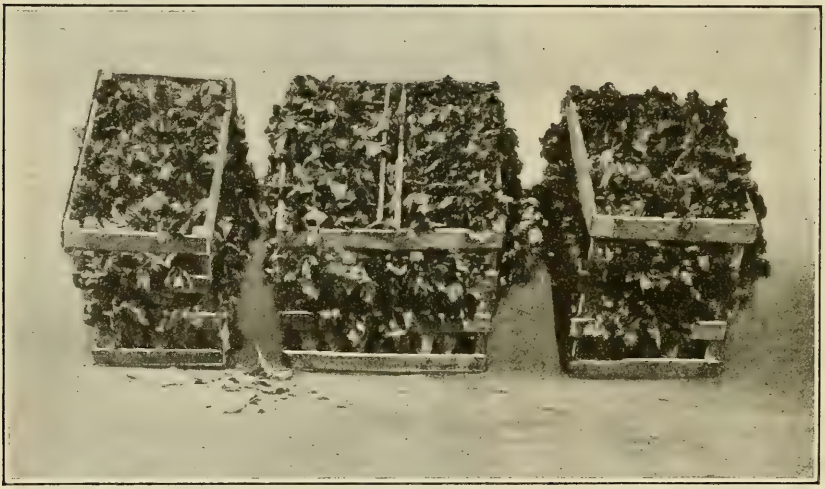

FIG. 3.—Three different types of crates used in the celery storage experiments: The 14-inch crate on the left, the partition crate in the center, and the 16-inch crate on the right.

After the celery had been in storage about 2½ months, half of it was sold without grading. Notes, however, were taken on its appearance, and while none of it had decayed to any considerable extent, there was a great deal of difference in the color of the foliage in the several crates. The tops of the celery in the standard crate had turned yellow, and decay had started in the center of the crate. The dealer who handled this shipment stated that the celery in the standard crate was worth from 10 to 15 per cent less than that in the partition crates and in the smaller crates.

The remaining five crates of each lot of celery were taken out on February 13, 1914, and carefully graded. The results are given in Table II.

TABLE II.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Elmira, N. Y., when inspected on February 13, 1914.*

| Type of crate. | Total number of stalks. | Sound. |  | Slightly decayed. |  | Badly decayed. |  | Worthless. |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| Standard | 615 | 230 | 37.4 | 240 | 39.0 | 115 | 18.7 | 30 | 4.9 |
| Partition | 480 | 310 | 65.0 | 135 | 28.0 | 25 | 5.0 | 10 | 2.0 |
| 16-inch | 430 | 335 | 77.9 | 78 | 18.0 | 17 | 4.0 | 0 | 0 |
| 14-inch | 370 | 300 | 81.0 | 60 | 16.2 | 10 | 2.7 | 0 | 0 |

The celery harvested in 1913–14 was quite small, because a severe freeze on September 14 killed the outside leaves, necessitating more stripping than usual. Table II shows that the celery was separated into four grades. The sound and slightly decayed grades corresponded to those used in 1912–13. "Badly decayed" consisted of celery so badly diseased that when the stalks were prepared for market only hearts remained. "Worthless" consisted of stalks which were completely decayed and therefore a total loss. The standard crates contained less sound and more slightly decayed, badly decayed, and worthless celery than any of the other crates. The largest percentage of sound celery was in the 14-inch crates, followed by the 16-inch, the partition, and the standard crates, in the order given. Nearly 5 per cent of the celery in the standard crate was a total loss, and over 18½ per cent was hearts.

## EXPERIMENTS IN 1914–15.

In the 1914–15 experiments, the celery was secured from two different localities, half being grown at Arkport and stored at Hornell, N. Y., and the other half being grown and stored at Williamson, N. Y. Records were kept to determine the relative development of decay in celery in crates in the different tiers. The top tier always showed more rot than any other.

The celery from Arkport and Williamson was grown and handled under such different conditions that it seems advisable to give the results separately.

### CELERY GROWN AT ARKPORT.

At Arkport six lots of five crates each were packed, as follows:

*Lot 1.*—Standard crate. The celery in this lot was harvested on October 19, while still wet after a rain, and hauled direct to a box car.

*Lot 2.*—Standard crate. This celery was harvested on October 19, when dry, and left exposed to the sun for about five hours before being loaded into the car.

*Lot 3.*—Standard crate.

*Lot 4.*—Partition-ventilated crate.
*Lot 5.*—16-inch crate.
*Lot 6.*—14-inch crate.

Lots 3, 4, 5, and 6 were harvested on October 20, while the celery was dry, and loaded immediately into a box car. The car, which was left on the siding until the last of the celery was loaded, was delivered to the storage house the same evening, October 20, but it was not unloaded until the following afternoon, about 5 o'clock. This celery was graded on January 22, 1915, with the results given in Table III.

TABLE III.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several lots stored at Hornell, N. Y., when inspected on January 22, 1915.*

| Lot No. and type of crate. | Total number of stalks. | Sound. |  | Slightly decayed. |  | Badly decayed. |  | Worthless. |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| 1, standard | 429 | 199 | 46.7 | 193 | 45.3 | 37 | 8.0 | 0 | 0 |
| 2, standard | 391 | 167 | 41.7 | 174 | 46.2 | 49 | 12.1 | 1 | .2 |
| 3, standard | 412 | 195 | 47.3 | 195 | 47.3 | 21 | 5.0 | 1 | .2 |
| 4, partition | 348 | 274 | 78.7 | 70 | 20.1 | 4 | 1.1 | 0 | 0 |
| 5, 16-inch | 272 | 235 | 86.4 | 37 | 13.6 | 0 | 0 | 0 | 0 |
| 6, 14-inch | 261 | 243 | 93.1 | 18 | 6.9 | 0 | 0 | 0 | 0 |

Table III shows that there was little difference in the keeping quality of the celery in the first three lots. Lot No. 2, which was exposed to the sun for about five hours, had the smallest percentage of sound celery. By comparing lots 3, 4, 5, and 6 it will be seen that the partition crate and the two smaller crates gave much better results than the standard crate. The 14-inch crate gave the best results, followed by the 16-inch crate and the partition crate in the order given. In the standard crate, less than one-half of the celery was sound, while in the 14-inch crate 93 per cent was of that grade.

Table IV shows the relative keeping quality of celery stored at different heights in the Hornell storage house. Each of the six lots was piled in a separate stack, five crates high. These piles were 2 to 3 inches apart, and the crates in each pile were separated by 2 by 2 inch scantlings. The tiers as given in Table IV included one crate from each of the six lots.

It will be noticed that the celery in the bottom tier kept much better than that in any other. At the time the celery was graded the top tier contained only about one-third as much sound celery as the bottom tier.

The celery stored at Hornell was held until February 8, 1915, but as there had been no other celery in the room for two or three weeks preceding that date, it was difficult to maintain the proper temperature, and the experimental celery was badly frozen. For this reason it was not graded a second time.

TABLE IV.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in each of the five tiers of crates at Hornell, N. Y., when inspected on January 22, 1915.*

| Tier. | Total number of stalks. | Sound. | | Slightly decayed. | | Badly decayed. | | Worthless. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| First (bottom) | 428 | 386 | 90.2 | 41 | 9.5 | 0 | 0.3 | 0 | 0 |
| Second | 412 | 283 | 68.7 | 128 | 31.0 | 1 | .3 | 0 | 0 |
| Third | 426 | 293 | 68.8 | 131 | 30.7 | 2 | .5 | 0 | 0 |
| Fourth | 414 | 216 | 52.1 | 195 | 47.1 | 3 | .8 | 0 | 0 |
| Fifth (top) | 434 | 135 | 31.1 | 192 | 44.2 | 105 | 24.2 | 2 | .5 |

## CELERY GROWN AT WILLIAMSON.

The celery grown and stored at Williamson was harvested and packed in the afternoon of October 23, 1914, and hauled to the storage house the same afternoon. This celery was large, free from disease, and blanched nearly enough for market.

Five crates each of five different types were used, as follows: (1) Standard crate, (2) partition-ventilated crate, (3) 16-inch crate, (4) 14-inch crate, (5) 11-inch solid-head crate.

The crates were of the same length and depth, the difference in size being in width only. Each lot of five crates was piled five high, with 3 or 4 inches between the crates in the piles. The celery was examined on January 20, 1915, but was not graded until February 12. The results of this grading are given in Tables V and VI.

TABLE V.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Williamson, N. Y., when inspected on February 12, 1915.*

| Type of crate. | Total number of stalks. | Sound. | | Slightly decayed. | | Badly decayed. | | Worthless. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| Standard | 383 | 146 | 38.0 | 163 | 42.5 | 61 | 16.0 | 11 | 3.4 |
| Partition | 334 | 207 | 61.4 | 102 | 30.5 | 20 | 6.0 | 5 | 1.5 |
| 16-inch | 260 | 152 | 58.4 | 89 | 34.2 | 14 | 5.3 | 5 | 1.9 |
| 14-inch | 229 | 146 | 63.7 | 65 | 28.0 | 12 | 5.2 | 6 | 2.6 |
| 11-inch | 181 | 116 | 64.0 | 53 | 30.0 | 9 | 5.0 | 3 | 1.6 |

Table V shows that the best results were secured in the 11-inch crate and the poorest in the standard crate. The bottom crate in lot No. 2 was perfect and brought up the average for that lot. Why this particular crate was so much better than any other is not known.

The difference between the keeping quality of the celery stored in this house and that stored at Hornell is probably due to the conditions under which it was handled before reaching the storage houses. The celery stored at Hornell was shipped from Arkport and had a chance to heat before being unloaded, while the celery at Williamson was hauled direct from the field to the storage house.

TABLE VI.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in the several tiers at Williamson, N. Y., when inspected on February 12, 1915.*

| Tier. | Total number of stalks. | Sound. | | Slightly decayed. | | Badly decayed. | | Worthless. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| First (bottom) | 284 | 188 | 62.7 | 87 | 30.6 | 11 | 4.6 | 8 | 2.7 |
| Second | 273 | 160 | 58.6 | 70 | 25.6 | 31 | 11.4 | 12 | 4.4 |
| Third | 268 | 161 | 60.0 | 84 | 31.3 | 17 | 6.3 | 6 | 2.2 |
| Fourth | 271 | 147 | 54.2 | 107 | 39.1 | 16 | 5.9 | 2 | .7 |
| Fifth (top) | 278 | 111 | 40.0 | 124 | 44.6 | 41 | 14.7 | 2 | .7 |

The difference between the keeping quality of celery in the bottom and in the top tiers was not so great at Williamson as at Hornell, due probably to the location of the refrigerating pipes. In the Williamson house all of the pipes are overhead, while in the Hornell house they are on the side walls and over the alleyways. There is less difference in temperature at different heights in the rooms of a house with overhead refrigeration than in a house where the refrigration is on the side walls and over the alleys.

## EXPERIMENTS IN 1915–16.

The celery used in the 1915–16 experiments was grown at Williamson and stored at Williamson and Hornell, N. Y. Both lots of celery were grown in the same field, handled in the same way, and harvested on October 21, 1915.

The following types of crates were used both at Hornell and at Williamson: (1) Standard crate, (2) partition-ventilated crate, (3) 16-inch crate, (4) 14-inch crate, (5) 11-inch solid-head crate.

### CELERY STORED AT HORNELL.

The celery stored at Hornell was loaded into a refrigerator car in the forenoon of October 22 and shipped the same day. The car was iced on October 20, reiced at Rochester, and reached Hornell on October 25, with the bunkers from one-half to two-thirds full of ice. The celery was unloaded in the forenoon of October 26 and piled immediately.

On December 20, 1915, the celery was inspected, with the results given in Table VII. The condition of the celery on this date was about the same as that of the 1914 crop after being held in storage one month longer.

TABLE VII.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades found in the several types stored at Hornell, N. Y., when inspected on December 20, 1915.*

| Type of crate. | Total number of stalks. | Sound. | | Slightly decayed. | | Badly decayed. | | Worthless. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| Standard | 340 | 153 | 45.0 | 163 | 48.0 | 24 | 7.0 | 0 | 0 |
| Partition | 320 | 246 | 76.9 | 70 | 21.8 | 4 | 1.25 | 0 | 0 |
| 16-inch | 286 | 243 | 85.0 | 38 | 13.2 | 5 | 1.8 | 0 | 0 |
| 14-inch | 230 | 207 | 90.0 | 22 | 9.6 | 1 | .4 | 0 | 0 |
| 11-inch | 193 | 168 | 87.0 | 21 | 10.9 | 4 | 2.0 | 0 | 0 |

Table VII shows that the celery in the 14-inch crate kept the best and that the three types of small crates and the partition crate gave much better results than the standard crate. The celery was left in the storage house until January 21, 1916; but as there had been no other celery in the room for two or three weeks it was frosted.

The difference in the keeping quality of celery stored at different heights in the Hornell storage room is shown in Table VIII.

TABLE VIII.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in the several tiers, at Hornell, N. Y., when inspected on December 20, 1915.*

| Tier. | Total number of stalks. | Sound. | | Slightly decayed. | | Badly decayed. | | Worthless. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| First (bottom) | 270 | 258 | 95.55 | 11 | 4.08 | 1 | 0.37 | 0 | 0 |
| Second | 276 | 228 | 82.60 | 47 | 17.00 | 1 | .36 | 0 | 0 |
| Third | 268 | 196 | 72.10 | 71 | 26.50 | 1 | .40 | 0 | 0 |
| Fourth | 281 | 190 | 68.60 | 88 | 31.30 | 3 | 1.10 | 0 | 0 |
| Fifth (top) | 274 | 145 | 52.90 | 97 | 35.40 | 32 | 11.70 | 0 | 0 |

It will be noticed that there was considerable difference in the keeping quality of the celery in the different tiers. The highest percentage of sound celery was in the bottom tier, and the lowest percentage in the top tier. The difference, however, was not so great in 1915–16 as in 1914–15, due to the fact that there was less celery in the room during the latter part of the storage period of 1915–16 than in the preceding year.

## CELERY STORED AT WILLIAMSON.

The celery grown and stored at Williamson was harvested on October 21, hauled direct to the storage house early in the morning of October 22, and piled exactly like that in the Hornell house. This celery was examined in December, but was not sorted until January 19, 1916. The temperature maintained in the storage room was not as uniform as it had been in 1914–15, so that the celery did not keep quite as well. On several occasions there was considerable drip from the pipes, and after this the temperature was reduced to below the freezing point, which froze the outside stalks. The results of the sorting of this celery on January 19, 1916, are given in Table IX.

TABLE IX.—*Relative keeping quality of celery stored in different types of crates, as indicated by the number of stalks of the different grades in the several types stored at Williamson, N. Y., when inspected on January 19, 1916.*

| Type of crate. | Total number of stalks. | Sound. |  | Slightly decayed. |  | Badly decayed. |  | Worthless. |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| Standard | 334 | 130 | 39.9 | 172 | 51.5 | 24 | 7.2 | 8 | 2.4 |
| Partition | 324 | 200 | 61.7 | 108 | 33.3 | 13 | 4.0 | 3 | .9 |
| 16-inch | 284 | 176 | 62.0 | 91 | 32.0 | 14 | 4.9 | 3 | 1.0 |
| 14-inch | 225 | 150 | 66.6 | 66 | 29.3 | 7 | 3.1 | 2 | .9 |
| 11-inch | 191 | 128 | 67.0 | 47 | 24.6 | 14 | 7.3 | 2 | 1.0 |

It will be observed that the highest percentage of sound celery was in the small crates, although the partition-ventilated crate gave almost as good results.

The difference in the keeping quality of celery stored at different heights in the Williamson storage room is shown in Table X.

TABLE X.—*Relative keeping quality of celery stored at different heights in the storage room, as indicated by the number of stalks of the different grades in the several tiers at Williamson, N. Y., when inspected on January 19, 1916.*

| Tier. | Total number of stalks. | Sound. |  | Slightly decayed. |  | Badly decayed. |  | Worthless. |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. | Number. | Per cent. |
| First (bottom) | 263 | 185 | 70.4 | 72 | 27.3 | 6 | 2.3 | 0 | 0 |
| Second | 277 | 190 | 68.6 | 77 | 27.8 | 10 | 3.6 | 0 | 0 |
| Third | 259 | 165 | 63.7 | 78 | 30.1 | 12 | 4.6 | 4 | 1.5 |
| Fourth | 291 | 154 | 53.0 | 116 | 40.0 | 15 | 5.1 | 6 | 2 |
| Fifth (top) | 268 | 90 | 33.6 | 141 | 52.6 | 29 | 10.8 | 8 | 3 |

A comparison of Tables VI and X shows that there was a greater difference in the keeping quality of the celery in the top and bottom tiers in 1915–16 than in 1914–15. This was probably due to the fact that there was more drip from the pipes and more variation in temperature in 1915–16 than in the preceding year.

## SUMMARY OF RESULTS.

### COMPARISON OF DIFFERENT TYPES OF CRATES.

Table XI shows the average percentage of celery of the four grades at the end of the storage period in the six types of crates used in the experiments. These figures are the averages for the six lots of celery used in the experiments during the four years 1912–13 to 1915–16, inclusive.

TABLE XI.—*Keeping quality of celery, as indicated by the average percentage of stalks of the different grades found at the close of the storage period in the several types of crates used during the four years, 1912–13 to 1915–16, inclusive.*

| Type of crate. | Grades (per cent). | | | |
|---|---|---|---|---|
| | Sound. | Slightly decayed. | Badly decayed. | Worthless. |
| Standard | 46.25 | 42.88 | 9.0 | 1.8 |
| Partition | 73.10 | 23.12 | 2.9 | .73 |
| 16-inch (for three years only) | 74.14 | 22.10 | 3.18 | .58 |
| 14-inch (for three years only) | 78.88 | 18.00 | 2.28 | .70 |
| 11-inch solid head (for two years only) | 72.66 | 21.83 | 4.75 | .86 |
| 10-inch (for one year only) | 97.00 | 3.00 | ........... | ........... |

An examination of Table XI shows that with the exception of the 10-inch crate, which was discarded after the first season because too small for practical purposes, the highest percentage of sound celery was in the 14-inch crate, followed by the 16-inch, the partition, and the 11-inch solid-head crate, in the order given. It is not quite fair to compare the 10-inch crate with the other crates, as it was used only one year, and in that particular year the celery in all of the crates kept better than in any other year.

The 14-inch and the 16-inch crates were not used the first year and the 11-inch solid-head crates were not used the first two years. It will be seen that the 11-inch crate did not give as good results as the other small crates and the ventilated crates. This was probably due to the fact that the 11-inch crate had solid heads, which excluded the air on the ends of the crates. It was observed that the stalks of celery in the ends of the 11-inch crate showed more decay than those in the ends of the crates which had slatted ends. The difference in the keeping quality of celery in the various crates is probably due to differences in temperature.

While celery temperature records were not made for all of the crates, those secured for the standard and partition crates in 1914–15 are of interest. The average temperature of the celery in the standard crate was 36.2° F. for the storage period (Oct. 24, 1914, to

Feb. 8, 1915), while the average for the partition crate was 34.2° F. for the same period. It should be noted, however, that these averages do not include the temperature for the cooling period (Oct. 21 to 24, 1914). Figure 4 shows graphically the rate of cooling of the celery in the standard and partition crates. It will be noticed that the temperature of the celery was quite high when the crates were placed in storage. This is due to the fact that it was shipped in a box car, which was left standing in the railroad yards for a day after reaching the storage center. The temperature dropped to 36° F. from 67° F. in the standard crate and 65° F. in the partition crate in about 60 hours. Figure 5 shows in graphic form the temperature of the celery in the standard and in the partition crates and of the air at the same height for the whole storage period of 1914–15.

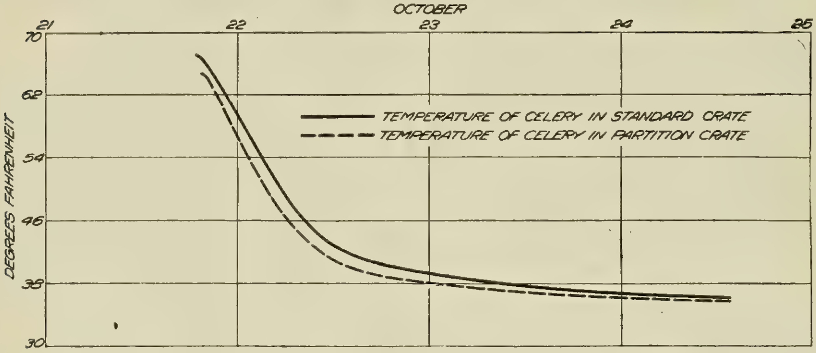

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FIG. 4.—Diagram showing the drop in the temperature of celery in the standard and partition crates during the cooling period, October 21 to 24, 1914.

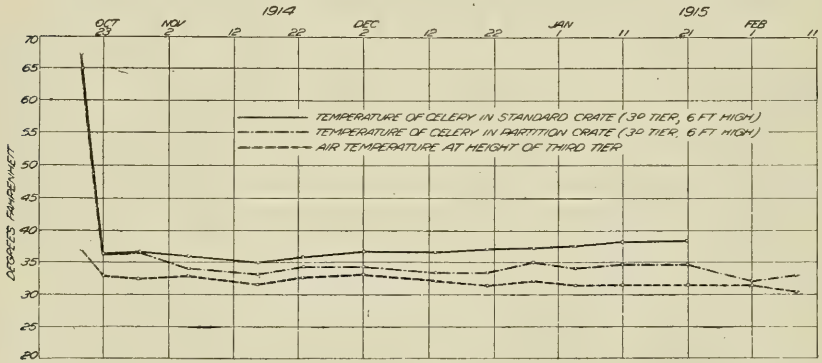

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FIG. 5.—Diagram showing the temperature of celery in standard and partition crates in the third tier (6 feet high) and of the air at the same height in the storage room during the storage period from October 21, 1914, to February 8, 1915.

### ESTIMATED CASH VALUE OF CELERY WHEN STORED IN DIFFERENT TYPES OF CRATES.

Table XII shows the estimated cash value of 1,000 bunches of celery, figured on the basis of the percentages given in Table XI, for the different grades of celery in each type of crate used in the experiments. The prices assigned for the different grades are as follows: 40 cents per bunch of 12 stalks for sound, 30 cents for slightly decayed, and 20 cents for badly decayed. Worthless celery consisted of stalks which were completely decayed and of no value. While the actual merchandising value of all the grades is usually higher and the difference between the grades is greater than the figures here used, it is believed that the prices assigned will serve for purposes of comparison.

TABLE XII.—*Estimated cash value of the different grades of celery in 1,000 bunches (12 stalks each) stored in each of the several types of crates, based on the percentages given in Table XI.*

| Type of crate. | Value of different grades. | | | | Total value. | Increase over standard crate. |
|---|---|---|---|---|---|---|
| | Sound. | Slightly decayed. | Badly decayed. | Worthless. | | |
| Standard | $185.00 | $128.64 | $18.00 | 0 | $331.64 | ........ |
| Partition | 292.40 | 69.36 | 5.80 | 0 | 367.56 | $35.92 |
| 16-inch | 296.56 | 66.30 | 6.36 | 0 | 369.22 | 37.58 |
| 14-inch | 315.52 | 54.00 | 4.56 | 0 | 374.08 | 42.44 |
| 11-inch solid head | 290.64 | 65.49 | 9.50 | 0 | 365.63 | 33.99 |

The value of 1,000 bunches (12,000 stalks) of celery stored in 14-inch crates would be $42.44 greater than for the same number of stalks stored in the standard crate. This is at the rate of 4.2 cents per dozen stalks, or 29.4 cents per crate of seven dozen, the average number held by the standard crates used in these experiments during the four years. With this yield of 143 crates per acre, 1,000 bunches, the increase in favor of the 14-inch crate over the standard crate would be at the rate of $42.44 per acre, but with a yield of 200 crates, which is not considered very high, the increase would be $58.80 per acre, even at the prices used in Table XII.

### COMPARATIVE COST OF CRATES.

While it must be admitted that the small crates cost more in proportion to their capacity, this difference is more than offset by the smaller amount of breakage. It is a well-known fact that much of the celery stored and marketed in standard crates is injured by the crates being broken in handling. In addition to this loss, the standard crates usually have to be repaired or remade before the celery reaches its destination, especially when it has been stored. Many counts were made of the broken crates in the storage house, and it was found that at least 25 per cent needed to be repaired or remade before being shipped from the storage house to the market; in fact, in one instance a carload of 168 crates had to be repacked before being shipped to market, and 125 new crates were required. The condition of these crates when they reached the storage house is indicated in figure 6. It can readily be understood that these crates would be in a much worse condition after being handled three or four times at the storage house and at least twice more en route to market. They did not, however, survive the handling at the storage house.

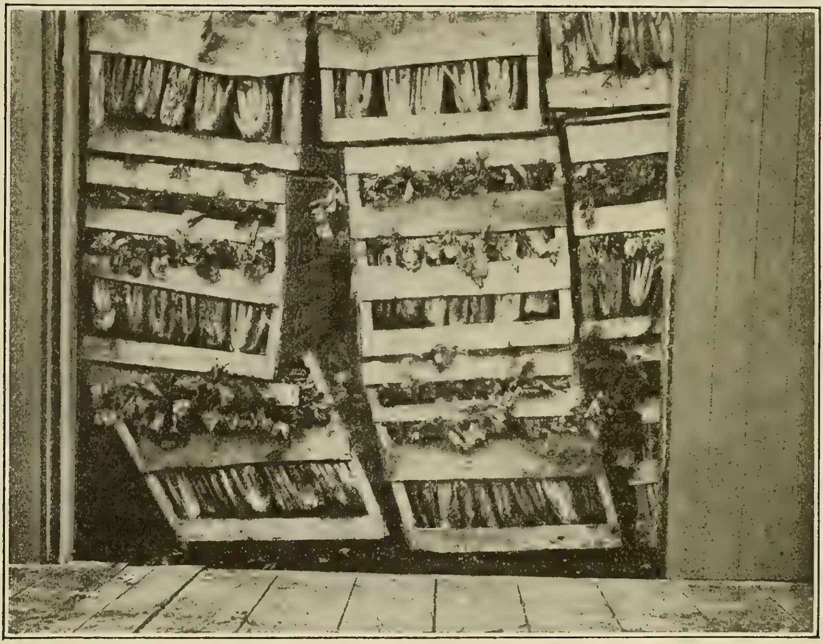

FIG. 6.—Celery in a refrigerator car as it reached the storage house. Note the broken crates and poor method of loading. This celery was repacked before being shipped to market and 125 new crates were used.

The partition crate gave nearly as good results as the 14 and 16 inch crates as far as the keeping quality of the celery was concerned, but there is the same objection to it as to the standard crate in that it is heavy and unwieldy to handle. A crate which is nearly square and weighs 125 pounds or more when full is hard to handle, and this is one reason why so many slats are broken in loading and unloading the filled crates. One crate is often dropped with considerable force on another crate, which results in the breaking of the top slats of the one or the bottom slats of the other. In lifting the large crates by their top slats the slats are often broken or pulled off. A broken crate does not stack well in a car or in the storage house, often tipping over in such a way as to crush the celery in the crates below. Much of the loss due to the breakage of the crates and the injury to the celery can be obviated by the use of smaller crates. The small crates are not so wide, and for this reason are more easily handled. They are made of the same material, and as they do not carry as much weight as the standard crate, seldom break in handling.

The average number of stalks of celery per crate in the 25 crates of the 14-inch size used in the experiments was 52.2, or 4.35 dozen; in the same number of 16-inch crates 61 stalks, or 5.1 dozen; while the average for the standard crate was 84 stalks, or 7 dozen. The comparative cost of the crates needed to hold 1,000 bunches (12,000 stalks) of celery, based on the capacity of the different-sized crates as given above and figured at 18 cents for the standard crate, would be about as follows:

| | |
|---|---|
| 143 standard crates, at 18 cents each | $25. 74 |
| 196 16-inch crates, at 17 cents each | 33. 32 |
| 230 14-inch crates, at 16 cents each | 36. 80 |

As already mentioned, the difference in cost in favor of the standard crate would be more than offset by the expense of repairing them and the loss due to the injury to the celery itself. The appearance of the crate often determines the selling price of the celery. In other words, one lot of celery in good crates often brings from 50 cents to $1 more per crate than a similar lot in broken and patched crates. The time lost in repacking the celery when the crates are very badly broken should also be taken into consideration.

It might be argued that the storage charges for the small crates would be higher in proportion to their capacity than for the standard crates. While this might be true, many storage-house managers have indicated a willingness to base their charges on cubic capacity. Nearly all of the storage-house men interviewed favor the small crates, because they are easier to handle, less liable to get broken, and keep the celery in better condition.

Some growers have said that it would be difficult to sell celery in small crates because the trade is accustomed to the large crate and their prices are based on the latter. While it is true that most of the truck-crop celery grown in the North and in California is packed in large crates, all of the Florida celery is put up in small crates, 10 or 12 inches wide by 24 inches long. That small crates of celery are in demand on the market is evidenced by the sale of a carload of celery which included 127 large standard crates (22 by 24 inches) and 56 small (12-inch) crates.[1] These two lots of celery were grown and packed by the same grower, stored in the same room, and put on the market the same day. The price received for the 127 large crates averaged $3.93 per crate, and for the 56 small crates $2.576 per crate. The grower of this celery was at the New York market on January 10, when it was sold, and stated that the buyers seemed particularly pleased with the small crates, because of their size and the good condition of the celery they contained. The increased price received for the celery in the small crates was probably due partly to the fact that it was in better condition than that in the standard crates and partly to the fact that the small crate was of a more convenient size to handle. The small crate should be in demand for restaurants and retail stores.

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[1] The writer is indebted to Mr. Charles P. Russell, of Williamson, N. Y., for the information in regard to this carload of celery.

### COMPARISON OF THE KEEPING QUALITY OF CELERY STORED AT DIFFERENT HEIGHTS IN THE STORAGE ROOM.

No record was made of the difference in the keeping quality of celery stored at different heights in the storage room during the first two years of the experiments, and as the two storage houses in which the celery was stored during the last two years have different methods of piping, the results are tabulated separately. In the Hornell house the refrigerating pipes are located on the side walls near the ceiling and over the passageways, while in the Williamson house the pipes are distributed on the ceiling. The results for the past two years are given in Table XIII. It should be remembered that each tier consists of one crate each of the different types.

TABLE XIII.—*Keeping quality of celery stored at different heights in the storage houses at Hornell and at Williamson, N. Y., as indicated by the average percentage of celery of different grades in the several tiers, for the two years, 1914–15 and 1915–16.*

| Tier. | Grades at Hornell, N. Y. (per cent). | | | | Grades at Williamson, N. Y. (per cent). | | | |
|---|---|---|---|---|---|---|---|---|
| | Sound. | Slightly decayed. | Badly decayed. | Worthless. | Sound. | Slightly decayed. | Badly decayed. | Worthless. |
| First (bottom) | 92.75 | 6.79 | 0.33 | 0 | 66.55 | 28.95 | 3.45 | 1.35 |
| Second | 75.65 | 24.00 | .33 | 0 | 63.60 | 26.70 | 7.50 | 2.20 |
| Third | 70.45 | 28.60 | .45 | 0 | 61.85 | 30.70 | 5.45 | 1.85 |
| Fourth | 59.85 | 39.20 | .95 | 0 | 53.60 | 39.55 | 5.50 | 1.35 |
| Fifth (top) | 42.00 | 39.80 | 17.95 | .25 | 36.80 | 48.60 | 12.75 | 1.85 |

Table XIII shows that there was considerable difference in the keeping quality of celery stored in the different tiers at Hornell, the bottom tier being the best and the top the worst—in fact, the bottom tier contained 50 per cent more sound celery than the top tier.

A comparison of the figures in Table XIII shows that there was not as much difference in the keeping quality of celery stored at different heights in the storage house at Williamson as there was in the Hornell house. The difference in sound celery between the top and bottom tiers in the Williamson house was only about 30 per cent, whereas in the Hornell house the difference was 50 per cent. A possible reason for this difference is that in the Williamson house there was a more even distribution of temperature. It should be borne in mind, however, that the results in the two storage houses during 1914–15 and 1915–16 are not exactly comparable, as the celery was not graded at the same time. The celery stored at Hornell in 1914–15 was graded on January 22, 1915, and that stored at the same place during the past season was graded on December 20, 1915. The celery stored at Williamson during the two seasons was graded on February 12, 1915, and on January 19, 1916. In other words, the celery stored at Williamson was kept in storage nearly a month longer than that stored at Hornell. It is believed that the drip from the pipes in the Williamson house had more influence on the keeping quality of celery in the top tier of crates than the temperature. In other words, the difference between the celery in the top and bottom tiers of crates is due more to moisture in the top tier than to the difference in temperature at different heights. It is usually possible to so regulate the temperature that there is very little drip from the pipes, but during the season of 1915–16 this was not accomplished in the room where the experimental celery was stored. During the previous storage season the room was dry nearly all the time, and there was not a great difference in the amount of decay in the different tiers. There was a greater difference between the amount of sound celery in the fourth and fifth tiers than between that in the first and fourth tiers, as is shown in Table XIII.

The figures already given to show the difference in keeping quality of celery stored at different heights in the storage room do not show the variation due to the different types of crates. It seems desirable to compare the keeping quality of celery stored at the same heights in the different types of crates and at different heights in the same type of crates. Tables XIV and XV give these data for two lots of celery, one lot stored at Hornell and the other at Williamson, N. Y., during the storage period of 1914–15.

Table XIV shows that there was not a great difference in the different types of crates in the first tier, except in the partition crate. The high percentage of sound celery in the partition crate is due to the fact that in the Williamson house the celery in this crate was practically perfect, due to some unknown cause. In the fifth, or top, tier there was the greatest difference in the keeping quality of celery in the various types of crates. The partition crate contained 44.2 per cent more sound celery than the standard crate, the 16-inch crate 61.1 per cent more, and the 14-inch crate 76.9 per cent more. The standard crate contained a much larger percentage of badly decayed celery than any of the other crates.

TABLE XIV.—*Keeping quality of celery, as indicated by the average percentage of stalks of the different grades found in the several types of crates stored at different heights in the storage room, for two lots, at Hornell and Williamson, N. Y., respectively, in 1914–15.*

| Tier and type of crate. | Grades of two lots (per cent). | | | |
|---|---|---|---|---|
| | Sound. | Slightly decayed. | Badly decayed. | Worthless. |
| First (bottom): | | | | |
| Standard | 64.9 | 30.0 | 2.6 | 2.6 |
| Partition | 96.7 | 3.3 | 0 | 0 |
| 16-inch | 77.7 | 17.6 | 2.8 | 1.8 |
| 14-inch | 79.6 | 16.5 | 1.9 | 1.9 |
| Second: | | | | |
| Standard | 56.7 | 34.6 | 7.2 | 1.3 |
| Partition | 69.6 | 21.6 | 5.6 | 3.2 |
| 16-inch | 71.7 | 23.0 | 3.5 | 1.8 |
| 14-inch | 74.0 | 18.0 | 6.0 | 2.0 |
| Third: | | | | |
| Standard | 50.0 | 43.2 | 6.2 | .5 |
| Partition | 74.0 | 24.4 | .76 | .76 |
| 16-inch | 77.0 | 20.2 | 1.8 | .9 |
| 14-inch | 82.3 | 11.4 | 4.1 | 2.1 |
| Fourth: | | | | |
| Standard | 38.9 | 53.7 | 6.2 | 1.2 |
| Partition | 59.5 | 37.4 | 3.0 | 0 |
| 16-inch | 69.4 | 28.6 | 2.0 | 0 |
| 14-inch | 78.1 | 21.9 | 0 | 0 |
| Fifth (top): | | | | |
| Standard | 6.2 | 63.0 | 29.0 | 1.2 |
| Partition | 50.4 | 41.3 | 8.4 | 0 |
| 16-inch | 67.3 | 29.9 | 2.8 | 0 |
| 14-inch | 83.1 | 16.8 | 0 | 0 |

TABLE XV.—*Keeping quality of celery, as indicated by the average percentage of stalks of the different grades found at different heights in the storage room when stored in the several types of crates, for two lots, at Hornell and Williamson, N. Y., respectively, in 1914–15.*

| Type of crate and tier. | Grades of two lots (per cent). | | | |
|---|---|---|---|---|
| | Sound. | Slightly decayed. | Badly decayed. | Worthless. |
| Standard: | | | | |
| First (bottom) | 64.9 | 30.0 | 2.6 | 2.6 |
| Second | 56.7 | 34.6 | 7.2 | 1.3 |
| Third | 50.0 | 43.2 | 6.2 | .6 |
| Fourth | 38.9 | 53.7 | 6.2 | 1.2 |
| Fifth (top) | 6.2 | 63.0 | 29.0 | 1.2 |
| Partition: | | | | |
| First (bottom) | 96.7 | 3.3 | 0 | 0 |
| Second | 69.6 | 21.6 | 5.6 | 3.2 |
| Third | 74.0 | 24.4 | .76 | .76 |
| Fourth | 59.5 | 37.4 | 3.0 | 0 |
| Fifth (top) | 50.4 | 41.3 | 8.4 | 0 |
| 16-inch: | | | | |
| First (bottom) | 77.7 | 17.6 | 2.8 | 1.8 |
| Second | 71.7 | 23.0 | 3.5 | 1.8 |
| Third | 77.0 | 20.2 | 1.8 | .9 |
| Fourth | 69.4 | 28.6 | 2.0 | 0 |
| Fifth (top) | 67.3 | 29.9 | 2.8 | 0 |
| 14-inch: | | | | |
| First (bottom) | 79.6 | 16.5 | 1.9 | 1.9 |
| Second | 74.0 | 18.0 | 6.0 | 2.0 |
| Third | 82.3 | 11.4 | 4.1 | 2.1 |
| Fourth | 78.1 | 21.9 | 0 | 0 |
| Fifth (top) | 83.1 | 16.8 | 0 | 0 |

An examination of Table XV shows that the greatest difference in the keeping quality of celery between the top and bottom tiers was in the standard crate. The bottom tier contained 64.9 per cent of sound celery and the top tier only 6.2, a difference in favor of the former of 58.7 per cent. A study of Tables XIV and XV shows that the great difference in the keeping quality of celery stored at different heights, as shown in Table XIII, is due largely to the standard crate. In other words, with the small crates and the partition crates the difference between the different tiers is not great.

The difference in the keeping quality of celery at various heights in the storage room and in the several types of crates is probably due to differences in temperature. Figure 7 shows graphically the difference in the temperature of celery in the standard crates stored at different heights in the storage house in 1915–16. The temperature was recorded by means of air-soil thermographs, the soil bulb being placed in the center of the crate. Table XVI shows the average temperature of the celery in the standard crates and of the air at different heights in the storage room for the storage period from October 26, 1915, to January 21, 1916.

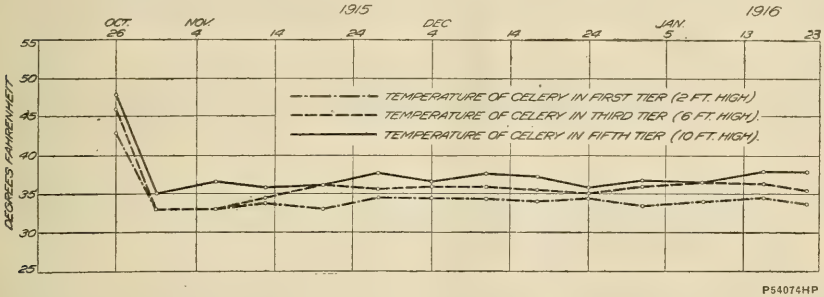

FIG. 7.—Diagram showing the temperature of celery in the center of standard crates at different heights in the storage room, during the storage period from October 26, 1915, to January 21, 1916.

TABLE XVI.—*Average temperature of celery in the standard crates and of the air in the storage house at Hornell, N. Y., from October 26, 1915, to January 21, 1916.*

| Tier. | Temperature (°F.). | |
|---|---|---|
| | Of celery. | Of air. |
| First (bottom) | 33.9 | 31.6 |
| Third | 35.8 | 32.8 |
| Fifth (top) | 36.6 | 33.8 |

Table XVI shows that the average temperature of the celery in the third tier was 1.9 degrees higher and that in the fifth was 2.7 degrees higher than that in the first tier. The temperature of the air was 1.2 degrees higher in the third and 2.2 degrees higher in the fifth tier than in the first tier. By comparing the air temperature and the celery temperature at the same heights in the room, it will be seen that the celery averaged 2.7 degrees higher than the air. Figure 8 shows graphically the air temperature at different heights in the storage room for the storage period, October 26, 1915, to January 21, 1916.

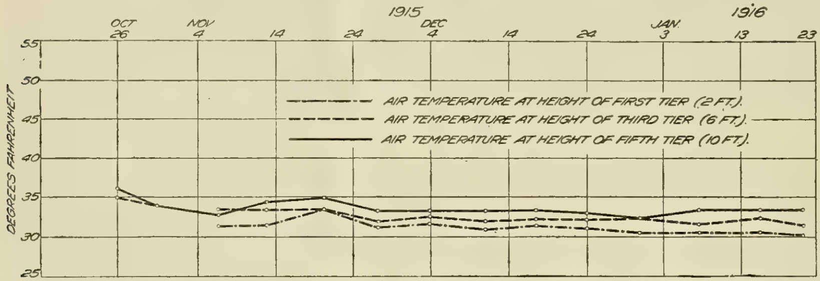

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FIG. 8.—Diagram showing the temperature of the air at different heights in the storage room during the storage period from October 26, 1915, to January 21, 1916.

Table XVII shows the average temperature of the celery in the standard and partition crates at the same height (third tier) and the air temperature at different heights for the storage period of 1914–15.

TABLE XVII.—*Average temperature of celery in standard and partition crates at the height of the third tier and of the air at different heights in the storage house at Hornell, N. Y., for the storage period of 1914–15.*

| Tier. | Air temperature at different heights. | Type of crate. | Celery temperature (third tier). |
|---|---|---|---|
| | *°F.* | | *°F.* |
| First (bottom) | 31.5 | Standard | 36.2 |
| Third | 32.1 | Partition | 34.2 |
| Fifth (top) | 33.9 | | |

Table XVII shows that the average air temperature at the height of the third tier was 0.6 of 1 degree higher and at the height of the fifth tier 2.4 degrees higher than at the height of the first tier. The average temperature of the celery in the standard crate was 2 degrees higher than that in the partition crate and 4.1 degrees higher than the air at the same height (fig. 5). Figure 9 shows graphically the air temperature at different heights in the storage room for the storage period, October 21, 1914, to February 8, 1915.

The rate of cooling of celery in standard crates at different heights in the storage house in 1915–16 is shown in figure 10, which indicates that the temperature began to drop in the bottom crate sooner than in the third-tier and top crates. A comparison of figures 4 and 10 shows that the temperature of the celery placed in storage October

21, 1914, was higher than that stored in the same house on October 26, 1915. The latter lot of celery was shipped to Hornell in a refrigerator car which had been iced before loading and was reiced in transit, while the 1914 lot was shipped in a box car and became somewhat heated before being unloaded.

While the temperature records given in this paper are not as complete as desired, a study of all the charts in connection with the keeping quality of celery in different types of crates and at different heights in the storage house shows quite clearly that there is a close relation between the temperature and the deterioration of the crop in storage. It will be noticed that the temperature was higher in the standard crate than in the partition crate (figs. 4 and 5) and that the celery and air temperature near the top of the room was always higher than near the bottom of the room (figs. 7 and 8). In every instance the largest proportion of decay was where the temperature was the highest. For this reason celery should be stored in crates in which there is the least difference between the air and celery temperature. In a large crate without a ventilator the tem-

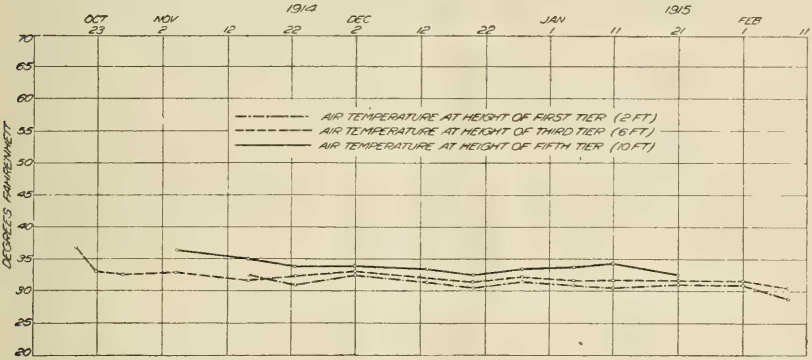

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FIG. 9.—Diagram showing the temperature of the air at different heights in the storage room for the storage period from October 21, 1914, to February 8, 1915.

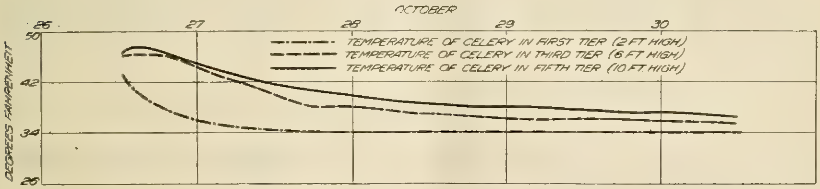

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FIG. 10.—Diagram showing the drop in the temperature of celery in the center of standard crates at different heights in the storage room for the cooling period, October 26 to 30, 1915. Note that the temperature in the bottom crate began to drop almost immediately.

perature of the celery in the center usually is several degrees higher than the temperature of the air. In the standard crate, 22 inches wide, the center of the celery is 11 inches from an air space, while in a crate 14 inches wide the center of the celery is only 7 inches from an air space.

The cold air being heavier than the warm air it naturally falls to the low levels and the warm air rises. An artificial system of circulation tends to equalize the temperature and prevents the formation of cold-air pockets. In most storage houses, the aim is to maintain a temperature of about 32° F.; but as the thermometers are usually placed a few feet from the floor they do not record the temperature near the top of the room, near the floor, or in the corners. Often when the thermometers register 32° F. the actual temperature at the height of the top tier of crates is 35° or 36° F., and near the floor and in the corners of the room the temperature is 2 or 3 degrees below the freezing point. The aim of the manager of the storage house should be to equalize the temperature and keep it as low as possible without allowing the celery to freeze severely. Slight freezing does no damage if the temperature is not raised quickly above the freezing point. In most storage houses, a temperature which does not freeze the outside stalks of celery in the lower tiers of crates is too high to maintain the celery in the top tiers in a satisfactory condition.

It is suggested that thermometers be placed at different heights throughout the storage rooms, in the corners as well as in the center passageways. All of these thermometers should be tested, and when the temperature shows much variation in the different parts of the room the air should be set in motion. This can be done by using fans or blowers, or by opening doors on opposite sides of the room when the outside temperature is about the same as the temperature in the storage house. Some houses are equipped with suction fans which draw off the warmer air at the top of the room. Cold air is then forced in.

## SUMMARY.

Celery is one of the important truck crops grown in the United States, having a farm value in 1909 of $3,922,848.

Six States—New York, Michigan, Massachusetts, Ohio, Pennsylvania, and New Jersey—produce about two-thirds of the celery crop, and a considerable portion of this is stored for a period of one to three months.

The old method of storing celery in the field and in houses of the cellar and semicellar type is not satisfactory, because temperature and moisture conditions can not be controlled.

The storage of celery in cold-storage warehouses is a comparatively new undertaking, and for this reason very little definite information is available on the subject.

In preliminary studies it was observed that celery stored in the large crates always began to decay in the center, and also that there was considerable injury to the celery due to the breaking of the crates.

As the celery decayed worse in the center of the crate than elsewhere, small crates and ventilated crates were used in the experiments. In every instance the decay was much less in the small and partition crates than in the standard crates.

Of the crates used during two or more years, the 14-inch crate gave the best results, followed by the 16-inch crate, the partition crate, and the 11-inch solid-head crate, in the order given.

The estimated value of 1,000 bunches (12 stalks each) of celery stored in the different types of crates is $331.64 for the standard crate, $367.56 for the partition crate, $369.22 for the 16-inch crate, $374.08 for the 14-inch crate, and $365.63 for the 11-inch solid-head crate.

The small crates cost a little more than the standard crate in proportion to their capacity, but this is more than offset by the smaller percentage of breakage.

The small crates are preferred by many storage-house managers and handlers of celery because of the ease of handling and the smaller amount of breakage.

In a market test made in January, 1916, celery in small crates sold for a much higher price than similar celery in standard crates handled in exactly the same way.

Celery in the top tier of crates showed a much larger proportion of decay at the end of the storage period than that in the lower tiers.

There was a greater difference in the keeping quality of celery in the different tiers where the standard crate was used than where the other crates were employed.

The difference in the keeping quality of celery in the different types of crates and at various heights was probably due to the difference in temperature and rate of cooling.

The air temperature at the height of the fifth tier averaged 2.4 degrees higher than at the height of the first tier during the storage period of 1914–15. The temperature of the celery in the standard crate averaged 2.7 degrees higher at the height of the fifth tier than at the height of the first tier during the storage period of 1915–16.

The temperature of the celery in the standard crate averaged 2 degrees higher than in the partition crate and 4.1 degrees higher than the air at the same height.

In most storage houses the temperature is recorded by means of thermometers placed a few feet from the floor. These do not show the temperature near the ceiling.

In many instances, when the thermometers register 32° F. within 4 feet of the floor the temperature is 35° to 36° F. near the ceiling.

Thermometers should be placed at various heights in the storage room and in the corners as well as in the passageways. When there is much variation in temperature in different parts of the room the air should be set in motion.

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**BULLETIN No. 580**

Contribution from the Forest Service
HENRY S. GRAVES, Forester

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# EFFECTS OF GRAZING UPON WESTERN YELLOW-PINE REPRODUCTION IN THE NATIONAL FORESTS OF ARIZONA AND NEW MEXICO.

By ROBERT R. HILL, *Grazing Examiner.*

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## IMPORTANCE OF PROTECTING PINE REPRODUCTION.

The best summer forage in Arizona and New Mexico is found among the open stands of yellow pine, mainly at elevations above 6,000 feet, and covering more than 8,800,000 acres, or 6 per cent of the total area of the two States. (See map, fig. 1.) Every economic consideration requires that this forage, one of the region's most important resources, should be converted into meat. At the same time, it is important that this should be done with the least possible injury to the yellow pine, which is by far the most important timber of the Southwest. In many places the tree is not reproducing satisfactorily, hence it is very necessary to protect the young growth (which in any event has to contend with severe winters, dry springs, and parasites and insects) from damage by stock.

The problem is especially important in the National Forests, which are created primarily to conserve the timber supply and to protect the vegetative cover on the watersheds. In the Forests is the bulk of the yellow pine in Arizona and New Mexico, and on the National Forest range are grazed approximately 30 per cent of all the range stock in the two States. Stock use the Forest range mainly during the summer, from April to November.

This bulletin presents the results of a study to determine the character and extent of the damage to young growth of western yellow pine in the Southwest from the grazing of live stock, and to find out the best means of keeping such damage at a minimum while permitting proper utilization of the range.

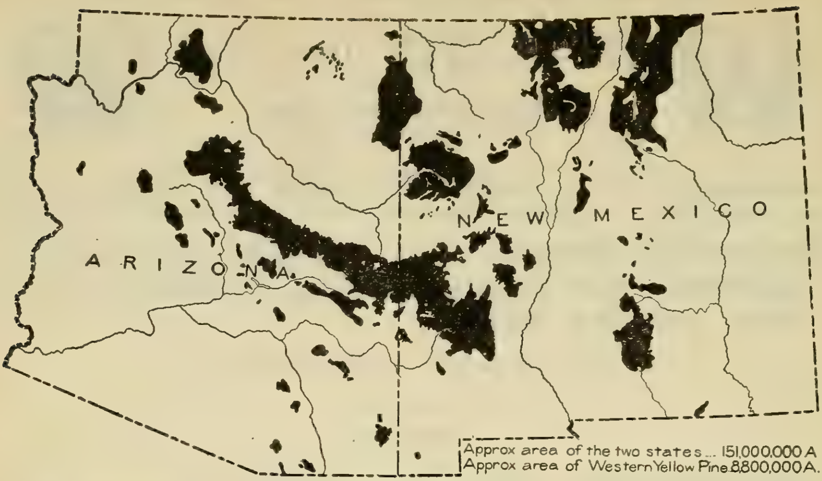

ARIZONA
NEW MEXICO
Approx area of the two states... 151,000,000 A
Approx area of Western Yellow Pine 8,800,000 A.

FIG. 1.—Yellow pine in Arizona and New Mexico.

## SCOPE AND METHOD OF STUDY.

An intensive study was made on the Coconino National Forest, in the north-central portion of Arizona, where grazing and timber conditions are typical of the forests of the Southwest, and where the problem of securing satisfactory timber reproduction is often serious. This was supplemented by general observations, covering a period of two years, on other Forests in Arizona and New Mexico. The observations were confined chiefly to the yellow-pine type, but for purposes of comparison some observations were made in the Douglas fir and piñon-juniper types.

Early in the season of 1910 a preliminary reconnaissance was made on the Coconino Forest. This was followed during that year by a detailed study, in which observations were made upon 150 plots. Further observations were made in 1912 on additional plots. Altogether 250 plots were observed within a radius of 25 miles of Flagstaff, in the heart of the Forest.

The plots were located so as to include the following range conditions:

(1) Areas embracing all conditions of range normally grazed by different classes of stock.

(2) Areas embracing all conditions of range overgrazed by different classes of stock.

(3) Areas supporting a good stand of forage normally grazed by all classes of stock.

(4) Areas supporting a poor stand of forage normally grazed by all classes of stock.

(5) Areas supporting chiefly bunch grasses, grazed by different classes of stock.

(6) Areas where cattle congregate.

(7) Areas where sheep congregate, *i. e.*, along driveways and on bed grounds.

The plots were selected where representative rather than abnormal injury was in evidence. In order to secure maximum results from a limited amount of work, the plots were located where the stand of seedlings was fair to good. They were laid out in quadrangles, varying in size from 10 feet by 30 feet to 30 feet by 90 feet, depending upon the size and density of reproduction.

All seedlings and saplings of a size subject to grazing were counted. An attempt was made at first to classify the damage according to such divisions as "leader destroyed," "needles removed," etc., but it was found that this did not give an accurate idea of the amount of damage actually done without a great deal of qualification. For this reason, it was decided to base the classification upon the permanent effect upon the development of the tree which, in the opinion of the observer, the damage would cause. Plants on which the leader, side shoots, and needles had been so severely grazed that the growth of the plant would be seriously interfered with for at least a number of years, were classed as "injured." Where the damage was not so severe, but if continued would seriously interfere with the development of the tree, the plants were classed as "severely browsed." Where the damage was severe enough to interfere to a very considerable extent with the development of the tree for a period of from one to three years, but not so severe as to affect its ultimate development even though the usual amount of damage were to continue, the tree was classed as "moderately browsed." Where the damage was so slight that its effect would not be noticeable after the current year, the plant was classed as "lightly browsed."

The trees were classified according to height by ocular estimate as follows:

| | |
|---|---|
| Below 6 inches | Seedlings. |
| 6 inches to 1.5 feet | 1-foot class. |
| 1.6 feet to 2.5 feet | 2-foot class. |
| 2.6 feet to 3.5 feet | 3-foot class. |
| 3.6 feet to 4.5 feet | 4-foot class. |
| 4.6 feet to 5.5 feet | 5-foot class. |
| 5.6 feet to as high as were subject to grazing | Above 5-foot class. |

Four examinations were made in 1912 and in 1913 at intervals during the grazing season to show the amount of seasonal damage. The first examination was made during May, to record the amount of damage at the beginning of the grazing period; the second examination was made early in July, to indicate the amount of damage that occurred during the spring dry period; the third early in September, to determine the amount of damage done during the best growing period; and the fourth early in November, at the close of the grazing season, to record the damage done during the fall drying period and also the total amount of damage during the entire grazing season. An examination was made also at the close of the 1914 grazing season. Thus data on seasonal damage are available for two years, and data on total annual damage for three years.

A supplemental study was undertaken in 1912 to determine the effects of protection from grazing upon the establishment, growth, and recovery of yellow-pine reproduction, and incidentally of forage plants. In each of five areas subject to close grazing and representative of soil classes and forage types in the western yellow-pine belt, 2-acre plots were fenced so as to exclude all grazing. Check plots, established in the immediate vicinity of the fenced plots, were left to the usual amount of grazing. The height and spread of crown of the young trees within the plots were measured, and the location of each tree was recorded. In addition, the severity and probable date of past grazing injuries were noted. These data were secured in 1912, 1913, and 1914. It is planned to repeat the examination every third year until a period of 10 years has elapsed, or until conclusive results are obtained.

## EXTENT OF DAMAGE TO WESTERN YELLOW-PINE REPRODUCTION FROM GRAZING.

### AVERAGE ANNUAL DAMAGE.

The average annual damage to western yellow-pine reproduction due to grazing under existing practice is shown in Table I. The figures are those obtained during the final examinations at the close of the grazing seasons of 1912, 1913, and 1914. It will be seen that 42 per cent of the total number of trees observed are damaged to some extent annually.

TABLE I.—*Annual damage to western yellow-pine reproduction from grazing.*

| Year. | Number of trees observed. | Injured. | | Browsed. | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Severely. | | Moderately. | | Lightly. | |
| | | Number. | Per cent of total. | Number. | Per cent of total. | Number. | Per cent of total. | Number. | Per cent of total. |
| 1912 | 8,945 | 853 | 9.5 | 1,035 | 11.6 | 2,240 | 25 | 896 | 10 |
| 1913 | 8,945 | 492 | 5.5 | 871 | 9.7 | 1,301 | 14.5 | 915 | 10.2 |
| 1914 | 8,945 | 448 | 5.0 | 589 | 6.6 | 698 | 7.8 | 382 | 4.3 |
| Average annual | 8,945 | 598 | 6.7 | 832 | 9.3 | 1,413 | 15.8 | 731 | 8.2 |

TABLE I.—*Annual damage to western yellow-pine reproduction, etc.*—Continued.

| Year. | Number of trees observed. | Rubbed. | | | | | | Dead. | |
|---|---|---|---|---|---|---|---|---|---|
| | | Severely. | | Moderately. | | Lightly. | | | |
| | | Number. | Per cent of total. | Number. | Per cent of total. | Number. | Per cent of total. | Number. | Per cent of total. |
| 1912 | 8,945 | 10 | 0.1 | 5 | 0.1 | 1 | 0.0 | 50 | 0.6 |
| 1913 | 8,945 | 54 | .6 | 46 | .5 | 20 | .3 | 94 | 1.0 |
| 1914 | 8,945 | 125 | 1.4 | 36 | .4 | 1 | .0 | 105 | 1.2 |
| Average annual | 8,945 | 63 | .7 | 29 | .3 | 7 | .1 | 83 | .9 |

In order to arrive at the number of trees damaged to such an extent as seriously to retard their growth, it is necessary, under the plan of classification, to include only the injured, the severely browsed, and the severely rubbed trees. Estimated on this basis, 1,493 trees, or 16.7 per cent of the total number examined, are subject to severe damage by grazing. It is this class of damage, rather than the total damage, that is of serious importance.

It is believed that the figures given represent fairly the actual damage over approximately one-half of the yellow-pine type on the Coconino Forest and that similar damage will occur elsewhere under like conditions. Conditions under which the damage is greater or less than the average are pointed out in the later discussions.

### DAMAGE BY HEIGHT CLASSES.

The extent of damage done to trees of different sizes is shown in Table II.

The conclusions drawn from this table are that damage is most severe in the seedling class and gradually shades off as the plants increase in size; that injuries and serious browsing constitute nearly all of the important damage to trees below 3.5 feet high, but that above this height most of the serious damage is due to rubbing, which becomes more acute with increase in height up to 5.5 feet.

Figure 2, which is constructed from the data in Table II, shows graphically the basis for these conclusions.

TABLE II.—*Damage by height classes.*

| Height class. | Number of trees. | Character of injury. | Damage. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Year. | | | Average for three-year period. | | |
| | | | 1912 | 1913 | 1914 | Total trees damaged. | Per cent of total trees in each class. | |
| | | | | | | | Damage of all classes. | Severe damage only.[1] |
| | | | *Number.* | *Number.* | *Number.* | *Number.* | | |
| Seedlings | 2,153 | Injured | 272 | 152 | 131 | 185 | 9 | 21 |
| | | Severely browsed | 322 | 352 | 143 | 272 | 12 | |
| | | Moderately browsed | 166 | 212 | 43 | 140 | 7 | |
| | | Lightly browsed | 91 | 121 | 19 | 77 | 4 | |
| | | Severely rubbed | | | | | | |
| | | Moderately rubbed | | | | | | |
| | | Lightly rubbed | | | | | | |
| 1-foot class | 3,294 | Injured | 385 | 232 | 203 | 273 | 8 | 18 |
| | | Severely browsed | 365 | 365 | 229 | 320 | 10 | |
| | | Moderately browsed | 553 | 587 | 301 | 480 | 14 | |
| | | Lightly browsed | 293 | 351 | 119 | 254 | 8 | |
| | | Severely rubbed | | | | | | |
| | | Moderately rubbed | | | | | | |
| | | Lightly rubbed | | | | | | |
| 2-foot class | 1,468 | Injured | 135 | 69 | 81 | 95 | 6 | 15 |
| | | Severely browsed | 195 | 75 | 125 | 132 | 9 | |
| | | Moderately browsed | 356 | 212 | 154 | 241 | 16 | |
| | | Lightly browsed | 207 | 159 | 54 | 140 | 11 | |
| | | Severely rubbed | | 1 | 1 | 1 | | |
| | | Moderately rubbed | | 1 | | | | |
| | | Lightly rubbed | | | | | | |
| 3-foot class | 1,212 | Injured | 55 | 37 | 32 | 41 | 3 | 12 |
| | | Severely browsed | 104 | 73 | 96 | 91 | 8 | |
| | | Moderately browsed | 238 | 229 | 156 | 208 | 17 | |
| | | Lightly browsed | 165 | 183 | 84 | 144 | 12 | |
| | | Severely rubbed | 2 | 23 | 26 | 17 | 1 | |
| | | Moderately rubbed | 1 | 6 | 4 | 4 | | |
| | | Lightly rubbed | | 4 | | 1 | | |
| 4-foot class | 324 | Injured | 5 | 1 | 1 | 2 | 1 | |
| | | Severely browsed | 11 | 9 | 11 | 10 | 3 | |
| | | Moderately browsed | 35 | 30 | 29 | 31 | 10 | |
| | | Lightly browsed | 89 | 73 | 42 | 68 | 21 | |
| | | Severely rubbed | 3 | 9 | 40 | 17 | 5 | |
| | | Moderately rubbed | | 7 | 3 | 3 | 1 | |
| | | Lightly rubbed | | | | | | |
| 5-foot class | 293 | Injured | 1 | | | | | 9 |
| | | Severely browsed | 3 | 2 | 5 | 3 | 1 | |
| | | Moderately browsed | 21 | 20 | 14 | 18 | 7 | |
| | | Lightly browsed | 40 | 36 | 42 | 39 | 15 | |
| | | Severely rubbed | 20 | 18 | 35 | 24 | 9 | |
| | | Moderately rubbed | 9 | 7 | 6 | 7 | 3 | |
| | | Lightly rubbed | 2 | 3 | | 2 | 1 | |
| Above 5-foot class | 201 | Injured | 1 | 1 | | 1 | | 6 |
| | | Severely browsed | | | | | | |
| | | Moderately browsed | | 1 | 1 | 1 | | |
| | | Lightly browsed | 72 | 16 | 21 | 20 | 10 | |
| | | Severely rubbed | 12 | 9 | 14 | 12 | 6 | |
| | | Moderately rubbed | 25 | 20 | 22 | 22 | 11 | |
| | | Lightly rubbed | 9 | 12 | | 7 | 3 | |

[1] Determined by adding per cent injured, per cent severely browsed, and per cent severely rubbed.

## DAMAGE BY PERIODS.

To determine the damage caused during different periods of the grazing season, four examinations were made of all plots during the seasons of 1912 and 1913. The first examination was made at the beginning of the grazing season; the second early in July at the close of the early summer drought; the third in the fore part of September, following the period of maximum plant growth; and the fourth early in November at the end of the grazing season. Results for the two years are summarized for the respective periods in Table III.

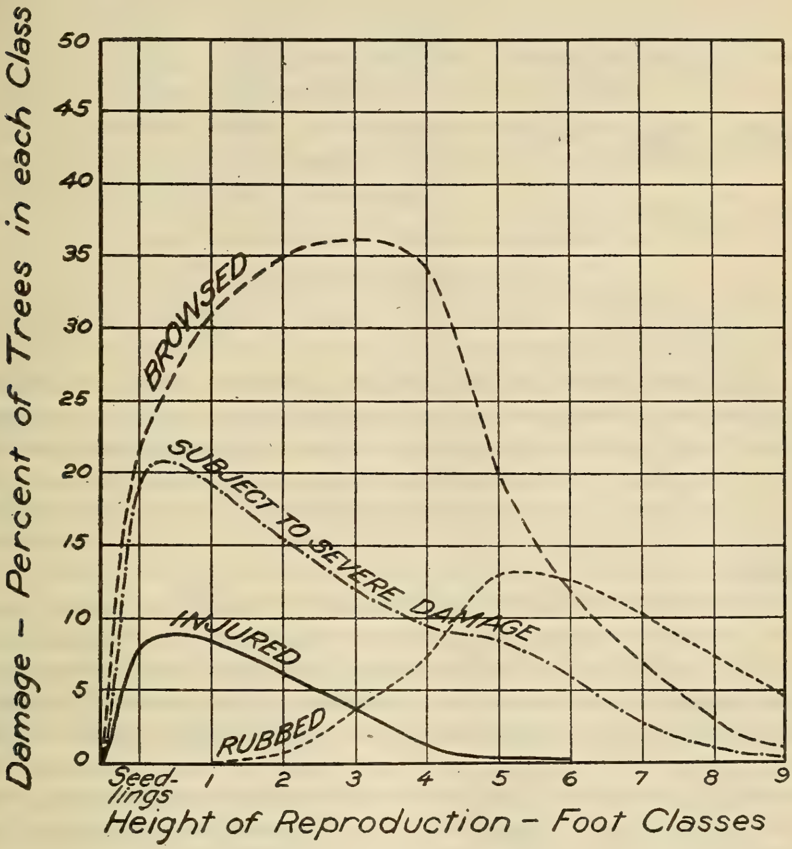


FIG. 2.—Extent of damage to reproduction of different heights.

TABLE III.—*Periodic damage.*

| Period. | | | | Year. | Total trees observed. | Per cent of trees found damaged at each examination. | Average per cent of trees damaged each grazing season. | Average per cent of trees damaged per week each grazing season. |
|---|---|---|---|---|---|---|---|---|
| No. of period. | Beginning. | Ending. | Number of weeks. | | | | | |
| First | Apr. 15 | May 20 | 5 | 1912 | 8,945 | 0.3 | 0.35 | 0.07 |
| | | | | 1913 | 8,945 | .4 | | |
| | | | | Average | 8,945 | .35 | | |
| Second | May 21 | July 8 | 7 | 1912 | 8,945 | 14.0 | 17.6 | 2.5 |
| | | | | 1913 | 8,945 | 22.0 | | |
| | | | | Average | 8,945 | 18.0 | | |
| Third | July 9 | Sept. 12 | 9 | 1912 | 8,945 | 35.0 | 17.5 | 1.9 |
| | | | | 1913 | 8,945 | 36.0 | | |
| | | | | Average | 8,945 | 35.5 | | |
| Fourth | Sept. 13 | Nov. 6 | 8 | 1912 | 8,945 | 46.0 | 7.5 | .9 |
| | | | | 1913 | 8,945 | 40.0 | | |
| | | | | Average | 8,945 | 43.0 | | |

The observations indicate that the greatest amount of damage occurs during the latter half of June and early in July, or during the severest portion of the early summer dry period, and that the least damage occurs during the first few weeks of the grazing period, or before June 1. A considerable amount of damage occurs during the main growing season and a smaller amount during the fall drying period.

The fact that a relatively small amount of damage occurred during 1914, which was unusually favorable for the growth of forage, gave support to the theory that the severity of damage varies inversely as the amount of succulent feed available. The record of periodic damage, however, indicates that there is an important factor besides the amount of available succulent forage which determines the severity of damage. This is believed to be the condition of the current year's growth of pine shoots. All observations substantiate the belief that, except in unusual cases, stock will not injure coniferous shoots of a previous year's growth. It has been noted particularly that during the early summer practically no damage occurs until new shoots appear, and that damage in any year is confined largely to that year's growth. Yellow-pine vegetative buds start active growth on the Coconino Forest about May 15, and by June 20 have formed succulent shoots with well-developed needles. From that time until about the middle of August the shoots are tender and more palatable than at other periods. Thus the season of best forage growth is also the period when yellow-pine shoots are most palatable. This and the probability that during the severe spring dry period stock develop a taste for the pine shoots which continues during the early portion of the summer growing period may explain the rather severe damage that continues through the season of abundant forage growth. The fact that the needles and stems become tough and therefore less palatable by September seems to account for the relatively little damage that is done during the fall period, when ordinary forage becomes dry and usually is closely grazed.

In 1912 the time of making the first count extended until early in June and in the preliminary study during 1910 until June 20. In neither of these counts was serious damage recorded. In view of this fact and of the indications based upon phenological observations, it is safe to say that very little serious damage is done to the reproduction before the middle of June.

## FACTORS INFLUENCING DAMAGE.

### INTENSITY OF GRAZING.

Casual observations indicate that the amount of damage to reproduction is greater on heavily grazed areas than on those lightly grazed. In order to determine the extent to which this apparent relation holds and the intensity of grazing which may be permitted without causing an undue amount of damage, plots were observed on ranges representing various degrees of utilization.

### NORMAL GRAZING.

Normal grazing, as the term is used here, implies that the class and number of stock are well adapted to the character and amount of forage.

Observations during 1912, 1913, and 1914 on 92 plots, representing a variety of forage types on ranges normally grazed by sheep, cattle, and horses, showed that out of a total of 3,352 trees an average of 126 were injured, 258 were severely browsed, and 1,023 were moderately to lightly browsed each year. Thus 384 trees, or 11 per cent of the entire number, were severely damaged.

Observations on 14 plots, containing 571 trees, on ranges normally grazed by cattle and horses only, showed no trees injured during the three-year period, none severely browsed, and only 11 moderately to lightly browsed. The number of plots in this series is perhaps insufficient to form the basis of general conclusions, but extensive observations elsewhere bear out the belief that cattle and horses, under proper conditions of grazing, do a negligible amount of damage to forest reproduction.

### OVERGRAZING.

By overgrazing is meant grazing by an excessive number of stock, with consequent injury to the palatable forage. Of 1,792 trees on two plots on ranges overgrazed by all classes of stock, an average of 298 were injured annually, 335 were severely browsed, and 474 were moderately to lightly browsed. Thus 633, or 35 per cent of the total number, were subject to severe damage.

Of 522 trees on 14 plots on an overgrazed range open to cattle and horses only, an average of 11 were injured annually, 55 were severely browsed, and 194 were moderately to lightly browsed. Thus 66 trees, or 13 per cent of the total number, were subject to severe damage. This injury is not excessive in itself, but when compared with the negligible injury which cattle and horses cause on normally grazed areas, it forms an additional reason for insisting upon the protection of the range against overgrazing, especially on areas where all of the established reproduction is needed.

The general conclusions from these observations are: (1) That on ranges properly grazed by sheep as well as by cattle and horses, a very considerable amount of damage occurs, but that where only cattle and horses graze under such conditions a negligible amount of damage results; and (2) that where overgrazing occurs serious damage is caused by any class of stock.

## DENSITY, AMOUNT, AND CHARACTER OF FORAGE.

### DENSITY OF FORAGE.

Since the intensity of grazing has a direct relation to the severity of the injury to tree reproduction, the inference might be drawn that on a range supporting a scattered stand of forage plants the percentage of trees damaged would be materially greater than on a range where the stand of forage is good. In order to determine whether this is so, observations were made on ranges where the average density of forage plants was less than two-tenths, and on ranges where the average density was four-tenths of the ground surface. The plots were selected as representing all degrees of grazing. On 39 plots supporting a good stand of forage and 1,010 trees, 31 trees were injured, 119 were severely browsed, and 255 were moderately to lightly browsed. Thus 150, or 15 per cent of the total, were subject to severe damage. On 92 plots, containing 3,678 trees, on range poorly stocked with forage, 157 trees were found to be injured, 500 severely browsed, and 882 moderately to lightly browsed. Thus 18 per cent of the total were being severely damaged.

These comparisons indicate that under average conditions there is not a great deal of difference in the amount of damage done on ranges well stocked with forage plants and on ranges poorly stocked. In general, therefore, it may be concluded that in a given forage type, with the same amount of forage allotted each animal, the density of the forage has little relation to the amount of damage to pine reproduction.

### AMOUNT OF FORAGE BY SEASONS.

The fact that a greater amount of damage occurs during the dry period of early summer, when ordinary forage is scarce, than during other periods of the grazing season suggests the probability that during a season when feed is unusually abundant the amount of damage will be relatively small. This supposition is confirmed by a comparison of the damage done in 1914 with that done in 1913.

Ordinarily not enough precipitation occurs during May and June to support the vegetative growth, and as a result not enough forage is produced to meet the needs of stock. This was the case in 1913; but in 1914 the dry period was broken in June by sufficient rainfall to revive the forage, and this was followed by abundant rainfall in July and August. Since the three months from June to August form the main growing period, 1914 was an unusually favorable year for the production of forage, and 1913 an unusually poor one. (See Table IV.)

TABLE IV.—*Precipitation during the growing periods of 1913 and 1914.*[1]

| Average for yellow-pine type. | May. | June. | July. | Aug. | Sept. |
|---|---|---|---|---|---|
| | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* |
| 1913 | 0.01 | 0.08 | 2.25 | 2.83 | 2.13 |
| 1914 | .49 | 1.45 | 4.54 | 2.47 | .74 |
| Average for 11 years (1902–1912) | .77 | .47 | 3.1 | 4.39 | 2.02 |

[1] The monthly rainfall is an average for the entire yellow-pine type, based upon the records at Fort Valley, Flagstaff, and Walnut Canyon.

TABLE V.—*Comparison of the serious damage caused by grazing during 1913 and 1914.*

| Year. | Trees seriously damaged. | |
|---|---|---|
| | Number. | Per cent of total. |
| 1913 | 1,417 | 15.8 |
| 1914 | 1,162 | 13.0 |

Table IV indicates that vegetation could not have made any considerable growth in 1913 before July, and the record of periodic damages shows that more than one-half of the total annual damage for that year occurred during this dry period. No record of periodic damage was kept in 1914, but a summary for the year (see Table V) reveals 13 per cent of the entire number of trees seriously damaged, as compared with 15.8 per cent for 1913. The lower per cent of damage for 1914 is believed to be due chiefly to the greater abundance of feed during that year, particularly during June and early in July.

This suggests the conservative use of forage as a means of preventing excessive injury to reproduction.

### CHARACTER OF FORAGE.

Observations were made to determine the relative amounts of damage to reproduction in the principal forage types of the yellow-pine belt.

Two main classes of forage are found in the yellow-pine type of the Southwest. These are the mountain bunchgrasses (*Muhlenbergia gracilis*, *Festuca arizonica*, and *Blepharoneuron tricholepis*) and blue grama grass (*Bouteloua gracilis*), which occurs usually on the more level mesas. Both types, with variations, are prominent on the Coconino Forest. The blue grama is very palatable to all classes of stock. The bunchgrasses, though very nutritious, are not generally preferred by any class of stock because of their accumulation of coarse, dry foliage.

The general conclusions regarding the relation of the intensity of grazing to the amount of damage to tree reproduction are believed to apply in the case of the grama range. But in the case of the bunchgrass type, a serious amount of damage occurs on some portions, even though the type is not grazed closely. A study was therefore made to determine which class of stock is responsible for such damage.

Since no bunchgrass areas are grazed exclusively by sheep, it was necessary, in order to determine the damage done by this class of stock, to compare the amount of damage done on bunchgrass areas by both sheep and cattle with that on similar areas grazed by cattle only. Accordingly 72 plots were selected in the bunchgrass type grazed moderately by both classes of stock. These plots contained 2,372 trees subject to grazing. During 1912 and 1913 counts on these plots showed an average of 428 trees injured and 320 trees severely browsed, or a total of 32 per cent which, if present conditions continue, may be expected to become seriously injured. On a number of the plots practically every tree had been killed by grazing. As compared with these figures there were no injuries or severe browses on the 15 plots in this type located on areas grazed closely by cattle only. Of the total of 618 trees only 7 were even moderately browsed.

The obvious conclusion that sheep are chiefly responsible for the severe damage is substantiated by the fact that the serious damage noted was characteristically that of sheep, that is, the needles were cropped closely along the stems, instead of the end of the shoot being eaten off.

It is not assumed that the injuries on the sheep-grazed areas are representative of the bunchgrass type as a whole. All of the plots studied were located in the north half of the Forest, where the bunchgrasses occur in much purer stand than over the remainder. In the rest of the Forest blue grama, Gambel's oak, and succulent weeds form a considerable percentage of the vegetation comprising the bunchgrass type. Extensive observations in this portion, supplemented by many others in the yellow-pine type in the Southwest, bear out the conclusion that where sheep are not forced to depend upon the rank growth of bunchgrasses for the main part of their feed, but have access to plenty of browse and palatable weeds, they will not cause such severe damage to yellow-pine reproduction in the bunchgrass type. If, however, the browse and weeds are not sufficient to supply the bulk of their feed, they are likely to cause very severe injury to young pines.

The portion of the bunchgrass type on the Coconino Forest, over which the damage is excessive, includes about one-third of the total, or 130,000 acres. A circumstance which makes the injury to reproduction here a serious matter is the fact that where the worst damage occurs reproduction is scattered, and for that reason is in special need of protection.

## CLASS OF STOCK AND METHODS OF HANDLING.

### CLASS OF STOCK.

It is comparatively easy to determine the amount of damage for which cattle, horses, and burros are each responsible, because frequently these classes of stock are handled in pastures where each may be observed separately. In the case of sheep, however, which are not handled in pastures on the Coconino Forest, but share the open range with other classes of stock, it is difficult to determine the proportion of the damage with which they can properly be charged. To arrive at a conclusion it was necessary to compare the amount of damage found on range occupied by both cattle and sheep with the amount of damage under similar grazing conditions on areas from which sheep are excluded and in pastures. This measure of sheep damage is believed to be fairly accurate, since there is no evidence that cattle do more damage to reproduction on a range which they share with sheep than on a range which they graze alone. Sheep injuries, furthermore, are characteristic and may be readily distinguished from those of cattle and horses.

It is believed that horses and burros may be eliminated from the classes of stock responsible for severe injuries to reproduction. The many saddle horses, in all kinds of physical condition, ridden in the yellow-pine type, have shown no disposition to eat coniferous reproduction. In a pasture 4 miles southwest of Flagstaff about 30 head of horses were grazed from May until November, 1910. The only other stock using the pasture were from three to five head of cattle and two or three head of sheep. The number of stock was greater than the carrying capacity warranted, and in the fall all forage was cropped very closely and the horses were poor and rough. Counts made in October showed that of 365 trees only 8 trees, or 2 per cent of the total, were seriously browsed. In a grama-grass weed pasture at Fort Valley, containing approximately 360 acres, about 12 horses were kept during the grazing season of 1910. Observations on 15 plots showed practically no damage.

Burros form a very small proportion of the total number of stock on the Forest. However, the fact that they often show little discrimination in the selection of their feed raises the question of the amount of damage which they do to forest reproduction. At the Rees's sheep-headquarters camp, located in the bunchgrass type on the north slope of the San Francisco Peaks, five burros were run during the seasons of 1913 and 1914 in a pasture containing about 160 acres. Observations made in October, 1914, upon 200 trees less than 4 feet in height showed no damage whatever by grazing.

The amount of damage under different range conditions on sheep-grazed areas and on areas from which sheep are excluded has already been discussed. In order, however, to estimate the relative damage chargeable to sheep and to cattle under average conditions in the yellow-pine type, range conditions has been given a weight in per cent representing the importance of each to the whole. The percentage of severe damage attributable to cattle and to sheep has been multiplied by the number representing the importance of each range condition and an average arrived at which represents the relative amount of damage for which these two classes of stock are responsible and the total per cent of damage which each class is believed to be causing over the entire Forest. The results are given in Table VI.

TABLE VI.—*Comparison of cattle and sheep damage.*

| Condition of range. | Comparative importance. Per cent of total. | Amount of serious damage (per cent of total stand). | |
|---|---|---|---|
| | | Cattle. | Sheep. |
| Normally grazed | 38 | 0.008 | 4.18 |
| Overgrazed | 6 | .78 | 2.10 |
| Poorly stocked with forage | 12 | .04 | .31 |
| Well stocked with forage | 28 | .08 | .62 |
| Bunchgrass | 15 | .001 | 1.50 |
| In flats | 0.92 | 0.20 | 0.20 |
| Around water and salt licks | .05 | .03 | .03 |
| Corrals, ranches, and bed grounds | .03 | .02 | .02 |
| Total | 100.00 | 1.159 | 8.96 |

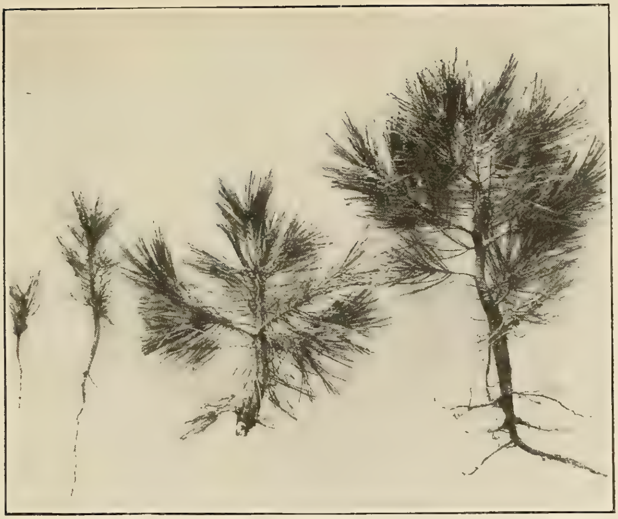


FIG. 1.—UNINJURED THRIFTY YELLOW-PINE REPRODUCTION FROM 4 INCHES TO 4 FEET TALL AND FROM 3 YEARS TO 14 YEARS OLD.

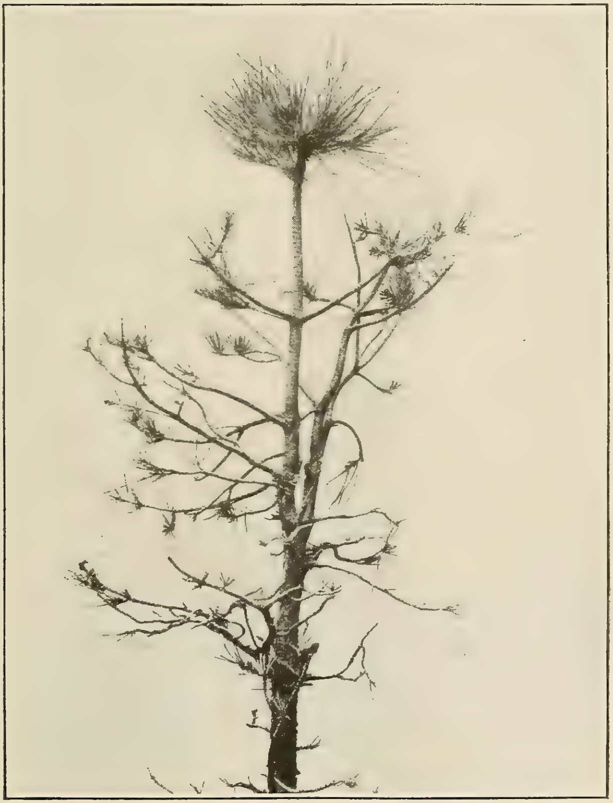


FIG. 2.—A YELLOW PINE 4½ FEET TALL, WITH LATERALS SEVERELY GRAZED BY SHEEP. LEADER OUT OF REACH OF THIS CLASS OF STOCK.

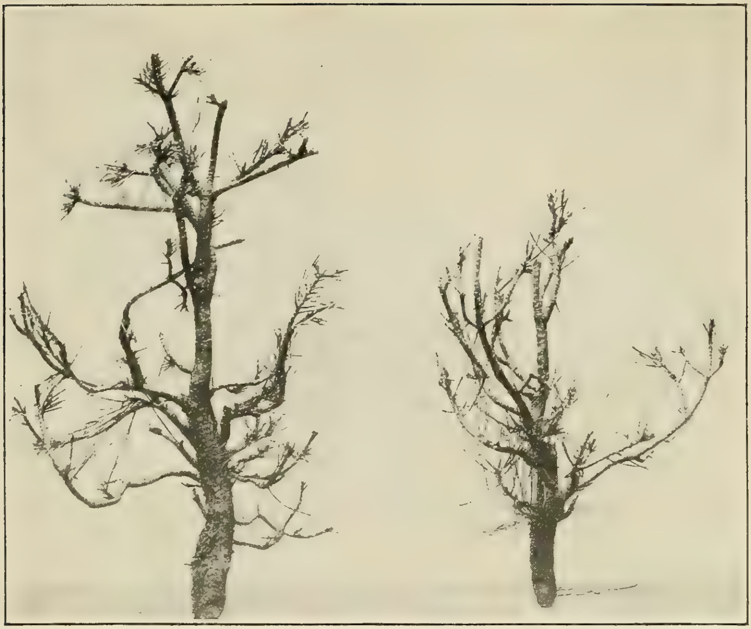


FIG. 1.—TYPICAL SHEEP DAMAGE. SHOOTS EATEN AND NEEDLES PULLED.

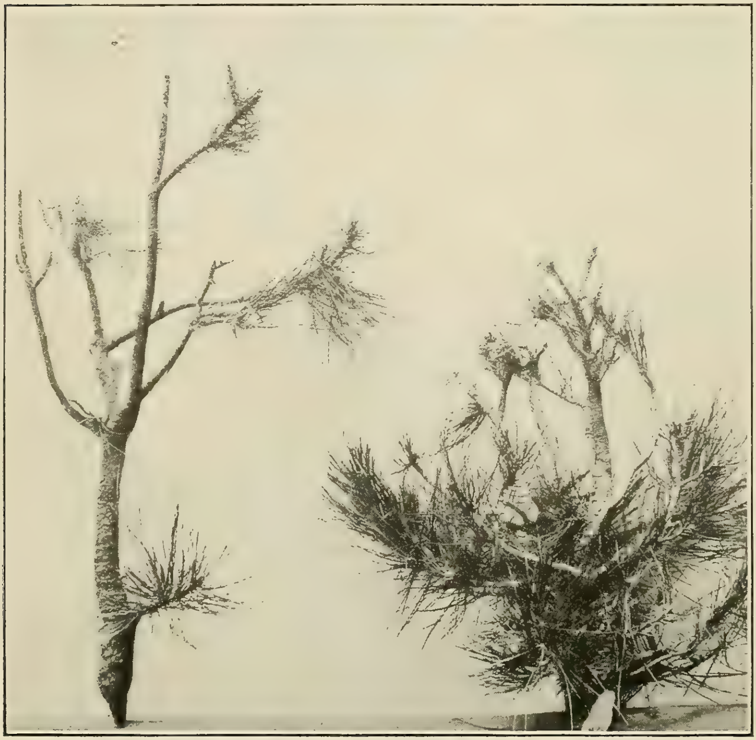
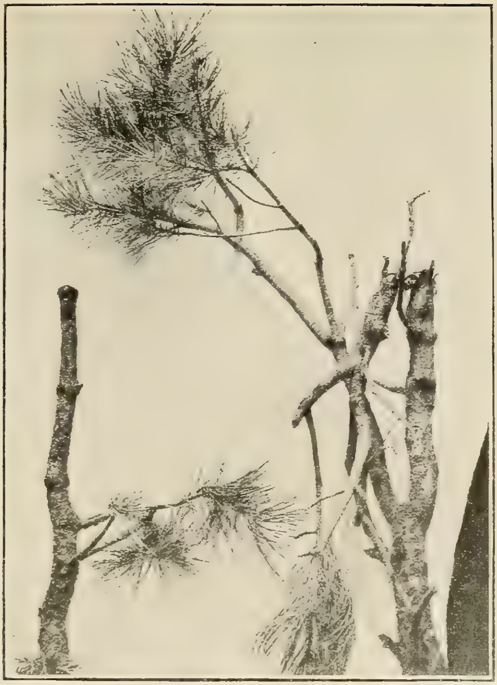
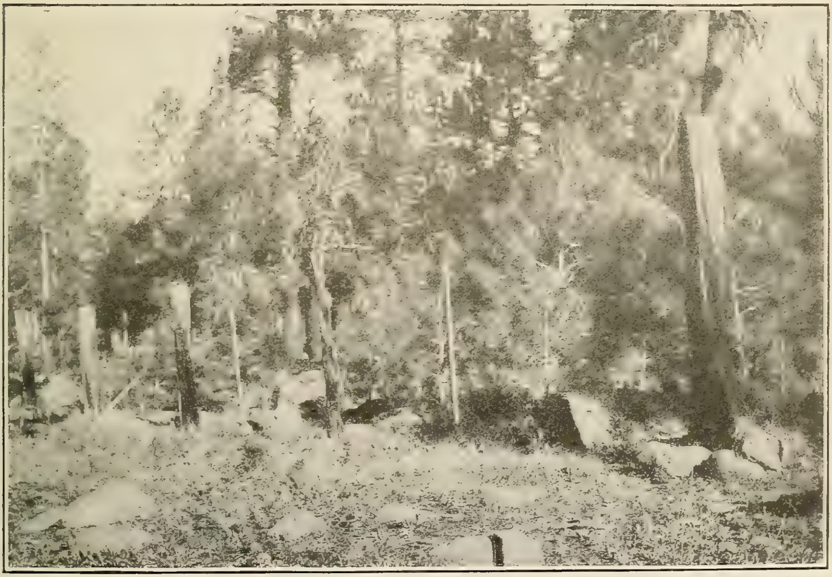


FIG. 2.—TYPICAL CATTLE DAMAGE. SHOOTS SEVERELY EATEN, BUT NEEDLES LEFT LARGELY INTACT.



F-5 RRH

FIG. 1.—WESTERN YELLOW-PINE SAPLINGS, 4 FEET AND 6 FEET TALL, SEVERELY INJURED BY CATTLE RUBBING.



F-6 RRH

FIG. 2.—A THRIFTY STAND OF REPRODUCTION IN A PASTURE AND A SCATTERED STAND OF BADLY INJURED REPRODUCTION ON THE OUTSIDE.

According to this table the ratio between the severe damage caused by cattle and that caused by sheep is approximately as 1 to 7.7. Striking variations from this ratio may be noted on the normally grazed areas and on the bunchgrass range. Over these portions of the type the damage caused by sheep is far out of proportion to that caused by cattle. On the other hand, in flats, around camps, and near water and salt licks the damage caused by each class of stock is about the same. On areas representative of the rest of the yellow-pine type the ratio of damage caused by cattle as compared with that caused by sheep approximates the average ratio of 1 to 7.7. This ratio is thought to be fair to the sheep. The proportion of reproduction severely damaged by both sheep and cattle is approximately 10 per cent. While this is not so high as the figure estimated for the half of the yellow-pine type under observation, which, according to Table I, amounts to 16.7 per cent, yet it is probably more nearly representative of the yellow-pine type as a whole.

The foregoing data point to the conclusion that stock do not eat yellow-pine reproduction through preference; that where the palatable forage is sufficient, reproduction will not suffer seriously from grazing; but that, on the other hand, where the palatable feed is not sufficient for the class of stock using the range, yellow-pine reproduction is likely to be seriously damaged.

### METHODS OF HANDLING.

From the conclusions reached under the preceding heading it is plain that the way stock are handled on the range has a most important bearing on the amount of damage that is done to reproduction. It has been pointed out, for example, that on bunchgrass range, which, under the methods of handling stock on unfenced range, at least is poorly suited to sheep grazing, this class of stock is likely to injure one-third of the stand of reproduction, as compared with an injury of 10 per cent of the stand on range well suited for sheep grazing and that the injury on an overgrazed range varies from three times the amount of damage on a normally stocked range to total destruction of the reproduction.

Further evidence as to the relation between the handling of stock and the amount of damage to reproduction is brought out by a study of the damage on areas where stock congregate.

*Rubbing by cattle.*—Over the Forest, as a whole, the principal damage caused by cattle is by rubbing. This damage is serious where cattle are accustomed to congregate, principally at the edges of parks, in alluvial flats, along drainage lines, and in the vicinity of watering places, corrals, and salt licks.

Counts were made on 17 plots located in situations subject to this kind of injury. Of 165 trees above 3 feet in height, and so of a size subject to severe damage by rubbing, 36 were seriously injured. Fifteen were so badly rubbed that they would become worthless if the rubbing continued, and 2 were moderately rubbed. Thus 22 per cent of the trees subject to this class of damage had been severely injured, and 9 per cent were being subjected to severe damage. In all, a total of 31 per cent would in time be killed. This indicates a serious condition over certain parts of the yellow-pine type. The sites on which such damage is most likely to occur support the best quality of timber.

*Damage along sheep driveways.*—In the southern part of the Forest the only places where pine reproduction seems to be injured are around watering places, near the lower boundary of the yellow-pine type where reproduction is scattered, and along the Mud Tank sheep driveway. This driveway, with an average depth of 1 mile, extends about 30 miles through the yellow-pine type. About 75,000 sheep are driven over it each year. Besides its use as a driveway, the strip is included in sheep and cattle allotments, and would be fairly well grazed by stock throughout the season without the additional use by transient stock. The first few bands find sufficient feed, but before the total number have crossed the feed is so short that sheep are forced to eat whatever growth is available, including a great deal of yellow-pine reproduction. The damage caused in this way is so severe that the boundaries of the driveway can readily be traced by the line of severe damage. Conditions on this trail are typical of a number of trails in Arizona and New Mexico. Good management requires that this damage be reduced to the minimum.

Around watering places and ranches where stock are allowed to congregate it is very common to find a majority of the reproduction badly deformed and stunted, as a result of browsing and rubbing.

## EFFECTS OF GRAZING INJURIES UPON WESTERN YELLOW-PINE REPRODUCTION.

### ESTABLISHMENT OF REPRODUCTION.

#### INJURIOUS EFFECTS.

Abundant reproduction is often found in pastures, while just outside, with no apparent change in natural conditions, it is relatively scarce. In all such cases observed the outside range had been subject to severe grazing by all classes of stock for a number of years after the pasture had been constructed. A comparison of the ages of reproduction within and those adjacent to the pastures indicates that the effect of severe grazing outside has been not only to prevent the establishment of reproduction, but also to kill many of the trees already established at the time the fences were built. This conclusion is supported by detailed observations made on small fenced areas on overgrazed ranges. One of these fenced areas, including about 2 acres, is located near the Bottomless Pits, 6 miles southeast of Flagstaff. At the time when the fence was constructed, in the spring of 1912, all reproduction in the vicinity had been badly injured by grazing for a number of years. During the three years from 1912 to 1914 the trees inside the fence were entirely protected, while those outside were subject to the same degree of grazing as formerly. A record was kept of the reproduction located within the inclosure and also of that on a check area of the same size near by. Of 57 trees within the inclosure only 5 died during the three years, whereas of the 45 trees on the check area 32 had died. Thus a loss of 9 per cent occurred among the protected trees, as compared with a loss of 71 per cent among the trees subject to continued grazing. While this contrast is unusual, it indicates the possible effects of very severe grazing.

Along most pasture fences which mark the line between good reproduction and scanty reproduction are also areas which have not been severely grazed. Where these begin the scanty reproduction ends.

It is asserted frequently that stock destroy a great many 1 and 2 year old seedlings. While this doubtless is true, it is also a fact that in inclosures entirely protected from grazing nearly all of the reproduction that germinates is killed by adverse natural agencies. Only during a series of favorable years does any considerable amount of reproduction become established. Observations in pastures and on sheep-excluded areas indicate that cattle and horses ordinarily do very little damage to reproduction of the seedling class, even though the larger trees suffer as a result of overgrazing. Though sheep probably do more or less damage to young pines during the first year, by far the greater number of such seedlings would die in any event during the following winter or spring.

At 2 years of age a seedling may be said to be well enough established to give it an even chance of survival against adverse natural agencies. For this reason the influence of grazing injuries after this period increases in importance. Table II indicates that injury to trees of the seedling class or to trees between the ages of 2 years and 6 years is more serious than in the case of larger trees. The fact that 21 per cent of trees of the seedling class are severely damaged indicates that grazing seriously handicaps young trees in becoming thoroughly established. Thus, though grazing is not a prime factor in the establishment of a seedling during its first or second year, it may seriously interfere with its growth after that age.

### BENEFICIAL EFFECTS.

Probably the only important ways in which stock aid in the establishment of reproduction are by helping to plant the seeds and by reducing the fire menace.

Sheep aid very materially in covering the seeds of grasses, thus helping to insure their germination.[1] It is reasonable to suppose that they aid in planting the seed of yellow pine. However, this aid is not very important, because the important problem in establishing a stand of reproduction is not to secure germination but to resist freezing during the following winter and starvation during the long dry period of the following spring.

Grazing, by preventing the accumulation of rank growth, plays no small part in preventing severe ground fires.

### HEIGHT GROWTH.

The extent to which the growth of young trees is retarded forms the most obvious index of the severity of the effects of grazing injuries. The effects upon height growth, however, indicate the immediate results of injuries and may or may not be a guide to the more permanent effects.

On Taylor's ranch, 9 miles northwest of Flagstaff, is a pasture in which the reproduction is abundant and free from injury. Just outside of the pasture damage by grazing has been very severe. Measurements of the height growth of saplings for the last five years within and outside the pasture gave the results shown in Table VII. Twenty trees form the basis for each height class.

TABLE VII.—*Comparison of height growth of trees in and outside of pasture.*

| Height class. | Growth of the average tree during last 5 years. | |
|---|---|---|
| | In pasture. | Outside of pasture. |
| *Feet.* | *Feet.* | *Feet.* |
| 1 | 1.02 | 0.6 |
| 2 | 1.45 | 84 |
| 3 | 1.97 | 97 |
| 4 | 2.53 | 1.26 |

The growth outside of the pasture is scarcely more than 50 per cent of that inside.

Measurements of 75 representative trees selected from three of the inclosures fenced in connection with this project in 1912 revealed an average growth of 0.7 foot for the three-year period, 1912–1914. Measurements of a similar number of trees growing in the check plots just outside these fenced areas showed an average height growth of 0.2 foot for the three-year period.

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[1] Journal of Agricultural Research, Department of Agriculture, Vol. III, No. 2, "Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation," by Arthur W. Sampson.

The rate of growth of 46 badly grazed saplings at Fort Valley, 9 miles northwest of Flagstaff, and 59 uninjured saplings of the same age in a pasture on Observatory Hill, just outside of Flagstaff, the two sites being very similar, are given in Table VIII.

TABLE VIII.—*Comparative growth of trees in pasture and on overgrazed range.*

| Location. | Number of trees. | Average age. | Average height. | Average annual growth. |
|---|---|---|---|---|
| | | *Years.* | *Feet.* | *Feet.* |
| In pasture | 59 | 17.2 | 5.2 | 0.36 |
| Overgrazed range | 46 | 17.0 | 2.1 | .12 |

The foregoing comparisons, which are believed to be representative, indicate that grazing injuries decrease the rate of growth of young trees from one-half to two-thirds.

From the standpoint of the production of a crop of timber this check in the growth of reproduction is not a serious matter, provided the trees have a chance to outgrow the injuries before their vitality is destroyed. The addition of 20 or 30 years to the period of rotation is not in itself a vital consideration in the management of yellow pine. Retarded growth is a serious matter, however, when it is considered that grazing conditions are generally stable and that where severe damage occurs the trees have no opportunity to outgrow their injuries, but are slowly killed.

### FORM OF TREE.

It is generally thought that the bole of a young tree that is severely injured is likely to become crooked or forked. This belief appears to have little basis in fact. The probable cause of crooked boles in nearly all instances is that the trees have at some time been overtopped or suppressed and in that condition have grown at an angle toward the strongest light, later becoming dominant or codominant and attempting to grow upright. Forked boles serious enough to be objectionable are formed at a height above that affected by grazing. Observations of a great many young trees recovering from severe injuries revealed no deformities that promised to be at all prominent when the trees mature. Nearly all grazing injuries occur at a height of less than 4½ feet, and the trees, when protected, very quickly develop a leader which gradually outstrips all others. The laterals of young trees made bushy by injuries contribute to the more rapid growth of the main bole.

### PERMANENT EFFECTS.

It is important to know what becomes of the seriously injured saplings. If they recover and become normal trees, then the ultimate effects of such damage are unimportant. But if a considerable portion of them die, and if others remain dwarfs or develop into deformed trees, then the need for applying protective measures is apparent. Owing to the slow growth of yellow pine, effects of grazing injuries upon the later development of reproduction requires a good many years to determine. Observations so far made, however, indicate clearly the effects that may be expected where injured reproduction is protected and where it remains subjected to continued severe grazing.

Observations of a great many trees formerly injured but later protected from grazing indicate conclusively that young injured pines have remarkable recuperative powers. Even though they have been eaten off repeatedly for as long as 10 years, a few years' protection will enable them to recover. Unless the injuries are particularly severe, the subsequent growth is as rapid as in the case of younger uninjured trees of the same height. Ordinarily, trees subjected to repeated grazing develop many laterals capable of supporting vigorous height growth at the first opportunity. When protection is afforded to such trees, the ultimate effects of the injuries appear to be simply the retardation of growth equivalent to the period of serious injury plus 5 to 10 years required for the plant to regain its normal vitality and to develop a well-defined leader. If, however, the young trees are defoliated, as is characteristic of severe sheep injuries, recuperation is necessarily very slow.

The ability of injured trees to recuperate if protected is well illustrated at the Fort Valley Ranger Station pasture. Previous to three years before the observations were made, the pasture had been greatly overstocked with cattle during certain portions of the year, but since that time it has been grazed only moderately. Reproduction is abundant, but during the period of overgrazing the saplings were severely damaged. Practically no damage was done in the three years preceding the observations. A comparison of the last three years' growth of saplings in the pasture previously injured, but showing no damage during this period, and of the growth during the same period of injured saplings just outside the pasture where severe grazing conditions prevailed, gave the results presented in Table IX. Twenty trees in each of four height classes were examined.

TABLE IX.—*Comparative growth of protected and unprotected saplings.*

| Height classes. | Average growth during 3 years. | |
|---|---|---|
| | In pastures. | Outside of pastures. |
| *Feet.* | *Feet.* | *Feet.* |
| 1 | 0.8 | 0.2 |
| 2 | 1.1 | .3 |
| 3 | 1.2 | .4 |
| 4 | 1.4 | .4 |
| Average | 1.1 | .32 |

The results show that the growth of the protected saplings is more than three times as rapid as that of the unprotected ones and indicate a marked ability of young pines when protected to recover from injuries. This conclusion is substantiated by the results of measurements of trees previously injured within the fenced plots and of trees outside subject to continued injury (p. 18). As stated in that case, the ratio of growth between protected and unprotected trees was as 7 to 2.

Even though protection against severe grazing may enable seriously injured saplings to recover, such protection may not be advisable unless the loss of young trees on unprotected areas is excessive. Reference to Table I shows that an average of only 0.9 per cent of the total number of trees were found dead during the three years covered by the study. While this loss probably represents the average mortality from grazing over the Forest as a whole, yet it does not adequately express the seriousness of the losses in certain important parts of the Forest. Areas exist where more than 50 per cent of the total number of young pines have been killed. Such areas include many sections of the bunchgrass type south and west of Lake Mary, the edges of parks, bedgrounds, driveways, the vicinity of headquarter ranches and water holes, and range areas that have been overgrazed for a long period.

It is estimated from a comparison of the age and height of 265 trees that a yellow pine will ordinarily, if uninjured, reach a height of 4.5 feet—above which it can withstand severe grazing injuries—when 15 years old, but that if it is subject to repeated grazing injuries it may require 35 years to reach this height. If it may be assumed that under average conditions which prevail over the Forest it requires 17 years for reproduction to reach a height of 4.5 feet, and that, as shown in Table I, 0.9 per cent of all trees observed die annually as a result of grazing injuries, it is safe to conclude that the loss of trees during the period when they are subject to severe grazing is approximately 15 per cent of the stand, or nearly as many as are seriously damaged each year in the north half of the yellow-pine type.

This poor showing of the injured trees would not be such a serious matter were it not for the fact that even though an injured tree does not die immediately, the needles, after repeated grazing, become dwarfed and turn yellowish, and the whole plant becomes stunted. If injury is continued the vitality is so weakened that a severe season or an attack by natural enemies is very likely to kill the tree. It is not uncommon to find saplings so impoverished by continued defoliation that they can readily be pulled out of the ground by hand.

The destruction of young trees is not such a serious matter where more reproduction has become established than is necessary to insure a complete regeneration of the stand. But where the reproduction is more or less scattered, the loss of a considerable percentage of young trees becomes decidedly important.

### SUSCEPTIBILITY TO FUNGOUS AND INSECT ATTACKS.

It is commonly supposed that young trees injured by grazing are more susceptible to attack by fungi and by insects than are uninjured trees. The extent to which this danger actually exists, and under what circumstances, is a subject which deserves careful consideration.

Dr. W. H. Long, forest pathologist for Arizona and New Mexico, who has made a special study of fungi attacking western yellow pine, has expressed the opinion that—

> The fungi and diseases known at the present time to cause serious damage to yellow pine in the Southwest normally do not enter trees through ordinary injuries caused by grazing. The spores of certain species of rust (*Peridermium* spp.) may enter through wounds in the living bark of pines, and it would be entirely possible for such spores to enter through wounds caused by grazing. However, the total damage due to such a rust entering through grazing wounds and finally girdling the trunks of yellow pine is probably very small.
>
> No heart-rotting fungus is known which is apt to start growth through grazing wounds other than in cases where the bark is removed or where the heartwood and sapwood are exposed by breaking and twisting. Since injuries of this character form a very small part of the total amount of damage, the danger of fungus attack due to them does not require serious consideration. Injuries that favor this kind of rot are caused by lightning, fire, deep blazes, etc.
>
> It might be presumed that mistletoe (*Razoumofskya* spp.) would be liable to attack grazing wounds, but a knowledge of the circumstances under which this parasite attacks tissue leads to the conclusion that this danger is relatively unimportant, for while it is true that mistletoe berries start growth where new tissue is exposed, such as on the calloused edges of blazes, and while the wounds to tender shoots such as are caused by grazing might afford favorable conditions for germination of these berries, the conditions are probably no more favorable than they are on the tips of uninjured stems.

Certain needle diseases exclusive of rusts are believed to attack dwarfed and unhealthy needles more readily than vigorous needles. Since the effect of moderate grazing wounds is to stimulate the growth of plant tissue, these needle diseases are not apt to secure a foothold more readily because of them. However, when persistent and severe wounds reduce the vitality of the trees until the needles reflect the weakened condition, certain needle diseases are apt to find favorable hosts. The total amount of damage caused by needle diseases or the increase in this character of damage which may be attributed to grazing is not known, although it is believed to be relatively unimportant.

During the last two years studies of the extent of damage by insects on the Forests of Arizona and New Mexico have been made a special study by A. J. Jaenicke, forest assistant in charge of insect studies. Mr. Jaenicke has expressed the opinion that grazing injuries are not responsible for a serious amount of insect damage to western yellow-pine reproduction. He states that—

> Western yellow-pine reproduction in Arizona and New Mexico suffers particularly from the following insects:
>
> 1. Tip moths of the genus *Retinia*. These kill the terminal shoots of the reproduction, causing it finally to assume a bushy form, but rarely kill it.
> 2. Engraver beetles of the genus *Ips*, particularly *Ips confusus* Leo. These insects are responsible for the death of considerable reproduction in various parts of the district, particularly on cutting areas.
> 3. Small scolytid beetles, which work in the thinner bark of the young trees and occasionally cause their death.
> 4. Flat-headed borer of the family of *Buprestidæ*. These were found doing serious damage on only one Forest in the district.
>
> During the past field season careful attention was given the relation of grazing injuries to attacks by the above-named insects. It was found that only in localities where serious overgrazing has taken place for a number of years is there ever any material increase in insect damage.
>
> The tip moth kills the terminal shoots of healthy and unhealthy reproduction with equal ease. Grazing injuries, therefore, are an unimportant factor in infestations by this insect.
>
> Wherever the vitality and health of reproduction has been seriously lowered by overgrazing or any other cause, particularly on areas recently cut over, engraver beetles may become responsible for the rapid death of the injured seedlings. The same is true of attacks by various small scolytids. Both the engraver beetles and small scolytids breed in slash, and so it is on the areas where there has been recent cutting that reproduction injured by grazing suffers most from these insects. It is not believed that attacks by flat-headed borers are increased by grazing injuries.
>
> The minor injuries caused by regulated grazing, therefore, are of little importance in augmenting insect attack. Even serious injuries are rarely responsible for insect damage of any consequence, except on recently cut-over areas.

## SUMMARY.

(1) Of 8,945 trees of a size subject to grazing, observed over a period of three years, 1,493, or 16.7 per cent, were severely damaged each year and 1,442, or 16.1 per cent, were moderately damaged.

(2) The most injured are the seedlings, 21 per cent of which are seriously damaged. The damage gradually decreases with an increase in the size of the trees. Trees above 4.5 feet in height are free from severe injuries from browsing, but those between 3 feet and 6 feet in height are likely to be rubbed severely.

(3) The greatest amount of damage occurs during the latter half of June and the first part of July, or when the effects of the spring dry period are most pronounced. The least damage occurs during the first few weeks of the growing period, or before June 15. A very considerable amount of damage is done during the main growing season and during the fall drying period.

(4) Under normal conditions of grazing cattle and horses, and incidentally burros, do an inconsiderable amount of damage to reproduction. Sheep under the same conditions may be responsible for severe injury to 11 per cent of the total stand.

On overgrazed areas all classes of stock are apt to damage small trees severely. Cattle and horses may damage about 10 per cent of all reproduction. Where sheep are grazed along with them, however, at least 35 per cent of the total stand may be severely damaged.

Cattle and sheep are responsible for practically all of the grazing damage to yellow pine on the Coconino forest. Ordinarily sheep cause about seven and a half times as much damage as cattle.

(5) The density of forage does not affect the amount of damage that may be caused on a given area.

(6) The suitability of the forage to the class of stock using a range has an important influence upon the amount of damage to timber reproduction. Because of the suitability of the pure bunchgrass type to sheep grazing, the reproduction over approximately one-third of the bunchgrass type on the Coconino Forest, or over 130,000 acres, is being seriously injured.

(7) The amount of palatable feed available during the grazing season, and especially during June and July, has an important bearing upon the amount of damage that grazing will cause to reproduction. During a favorable year the damage may be 18 per cent less than during a subnormal year.

(8) The manner in which stock is handled has much to do with the severity of grazing damage. Cattle are likely to injure 22 per cent of the trees between 3 feet and 6 feet in height that grow on areas where they are accustomed to congregate. Sheep severely injure reproduction along driveways and on bed grounds.

(9) Grazing is believed to have a largely neutral effect upon the germination and early establishment of reproduction, but to have an important effect in reducing the destruction of reproduction by fire.

(10) The effect of grazing upon the height growth of reproduction is marked. Severely injured trees grow only from one-half to one-third as fast as uninjured trees.

(11) Grazing injuries are not responsible for the common deformities of mature trees.

(12) The permanent effects of grazing injuries upon the development of the trees damaged are not serious, provided the damaged trees have a chance to recuperate. If grazing is unrestricted, about 15 per cent of the total stand is likely to be killed during the period required for reproduction to become established.

(13) Reproduction that has been impoverished greatly by grazing is more likely to be attacked by some fungi and insects than uninjured and vigorous reproduction. However, the ordinary grazing injuries are not believed to increase seriously the danger of such attacks.

## APPLICATION OF RESULTS TO RANGE MANAGEMENT IN THE SOUTHWEST.

The conclusions arrived at in this study are believed to be applicable over the entire yellow-pine type of the Southwest. Since forage composition, class of stock using a range, intensity of grazing, and methods of handling stock vary on different Forests, it is not advisable to attempt to prescribe specific suggestions for certain areas, but rather to prescribe definite remedies for certain conditions.

Under present conditions all reproduction should be protected against severe damage by grazing. Where immediate cutting of the mature stand is contemplated, the reason for protection is obvious, since the prime purpose should be to insure a stand of reproduction. Where reproduction on an area not to be cut over in the near future is being injured, protection is needed to assist nature in maintaining a forest cover. Reproduction generally occurs naturally in openings made by the death of mature trees. Unless this reproduction is protected, the gaps will tend to increase and the regeneration of the forest be made constantly more difficult. Moreover, under the most favorable conditions it is only through the combination of a good seed year with two or more good growing years following that any considerable amount of reproduction becomes established. Such a combination is so rare that it is not safe to depend upon it.

The grazing of stock on National Forests must be so regulated that the number of stock shall not decrease, but, if possible, shall increase. Under proper grazing management reproduction does not suffer an unwarranted amount of damage; in fact, the advantages of conservative grazing in reducing the loss of reproduction by fire probably offset the injury from stock. The application of conservative grazing throughout the western yellow-pine type, then, is the basis for the protective recommendations which follow.

Since overgrazing is the cause of the most severe grazing damage, it should be avoided by all means. An overgrazed condition may exist even though the general appearance of the range does not indicate it, as, for instance, on a bunchgrass range allotted to sheep. The principal grasses may be largely uneaten, while sheep feed, consisting of palatable weeds and grasses, and, too often, of yellow-pine reproduction, may be largely destroyed. Overgrazing may result from allotting too many stock to a range, or from poor distribution of a proper number of stock due to lack of sufficient well-located watering places, poor salting arrangements, or, in the case of sheep, to poor herding. In any case the cause should be determined and removed.

Sheep should not be depended upon primarily to utilize the bunchgrass range. This type should be utilized chiefly by cattle and horses, held in pastures if possible. On this type, wherever the bunchgrass species occur in nearly pure stand during early spring, sheep should be run in May and the fore part of June while the grasses are tender and most palatable. Where the succulent weeds and browse species occur in mixture with the bunchgrasses, sheep may be grazed season long together with cattle and horses.

Sheep should be excluded from cutting areas on which they are causing severe damage until reproduction is well established, usually for a period of from 15 to 20 years. They should be excluded also for a period of from two to five years from cutting areas where the stand of reproduction is deficient but has been supplemented by an abundant crop of seedlings which, having survived the first winter and spring, promise to become established, even though injury to the reproduction already established is not severe.

All stock should be worked and handled as little as possible around watering places, salting grounds, and headquarter ranches. Sheep should be bedded as seldom as possible on any one bed ground, preferably for one night only.

It is very difficult to avoid the damage caused by cattle rubbing. In exceptional cases, where complete reproduction is desired within a short period, as on a cutting area, flats might be fenced and cattle excluded from them during the fly season. However, if overgrazing and excessive handling are avoided, it is believed that the damage caused by cattle will not be excessive.

One of the most serious menaces to reproduction as well as to forage occurs on stock driveways. Even at best, an excessive number of stock must use these strips of range and injury can not be avoided. However, all practicable means should be used to conserve the stand of forage and by furnishing sufficient feed for the stock using the driveways to reduce the injury to reproduction to a minimum. In order to accomplish this, it is recommended that driveways be used as little as possible; that, wherever practicable, they be closed to grazing except by passing stock; that a sufficient number be established to prevent overgrazing; and that water be furnished in abundance at proper intervals along them.

Every effort should be made to protect yellow-pine reproduction in the "twilight" zone between the yellow-pine type and the juniper-pinion type. Conditions here are unusually unfavorable for yellow-pine reproduction, and such seedlings as become established should by all means be protected against grazing.

Stock, especially sheep, should not be held in the yellow-pine type during the winter, when they would be forced to eat reproduction.

Advantage should be taken of grazing as a means of fire control by securing proper utilization of all range where at present an accumulation of inflammable unused feed occurs each year. Such areas are common on the bunchgrass type and on other types of range far removed from water or located on rough ridges and slopes.

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UNITED STATES DEPARTMENT OF AGRICULTURE

# BULLETIN No. 581

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. ▼ October 6, 1917

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# MICROSCOPICAL STUDIES ON TOMATO PRODUCTS.

By Burton J. Howard, *Microscopist in Charge, in collaboration with* Charles H. Stephenson, *Scientific Assistant, Microchemical Laboratory.*

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## INTRODUCTION.

During the past few years the Bureau of Chemistry has conducted a very comprehensive investigation to establish a basis for judging tomato products. Experiments were conducted in the bureau laboratory and also in factories, a large number of which were visited. Out of the mass of data thus collected, it is felt that the scientific facts underlying the relationship between microorganisms and the rot and decay of tomato products should be of value to manufacturers and food control officials at this time. The results bearing upon the relation of the physical condition of the stock from which tomato products are made to the number of microorganisms present in tomato products are therefore given in this bulletin.

A great many tests at factories were made by noting the general condition of the stock and then examining microscopically samples of the finished product. The criteria published in 1911 in Bureau of Chemistry Circular 68,[1] for the guidance of manufacturers, were reached largely by such experiments. At that time very few tests had been made to correlate the amount of rot by weight with the microscopical counts. In the present discussion, therefore, the results obtained by visual inspection are considered first. The other series, that in which the percentage of rot was estimated, is discussed later (p. 8).

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[1] Sold by U. S. Superintendent of Documents Washington, D. C., for 5 cents.

## RELATION BETWEEN VISUAL INSPECTION AND MICROSCOPICAL EXAMINATION.

Tables 1 to 6, inclusive, and Tables 9 to 12, inclusive, show that a fairly concordant relationship exists between the character of stock as determined by visual inspection and the microscopic counts on the final product. In Bureau of Chemistry Circular 68 it was suggested that by good, sanitary practice the mold count could be kept down to 25 per cent or less, the yeast and spore count to 25 or less, per 1/60 cubic millimeter and the bacteria per cubic centimeter to 25 million or less. In only one instance in Tables 1 to 6 (Table 1, S 32) are these suggested limits exceeded on stock which to visual inspection appeared acceptable. In this sample the bacteria ran somewhat higher than is usual for passable stock. These results show that good stock properly handled almost never runs high in microorganisms.

In general, high counts of microorganisms are obtained on products made from stock which by visual inspection would be judged as objectionable or from stock which has been improperly handled. There seem to be, however, more exceptions to this rule than to that governing the microorganism count on products made from good stock. In three or four samples the counts are comparatively low on stock which to visual inspection appeared dubious. The few such exceptions which from time to time occur do not modify the fact that high counts of organisms indicate unmistakably that the stock used was in bad condition or that it was handled in an insanitary manner during manufacture. Either of these causes furnishes sufficient ground for condemnation of the product.

### TOMATO PULP.

The average of the counts on pulp from stock which appeared acceptable from a visual inspection (Table 1) is as follows: Molds in 8 per cent of the fields; yeasts and spores, 8 per 1/60 cmm; bacteria, 5,900,000 per cc. Table 2 gives the results of counts on pulp made from unacceptable or questionable stock. Taking averages of the counts in this table, excluding samples of questionable character, the following results are obtained: Molds, 51 per cent of the fields; yeasts and spores, 51 per 1/60 cmm; bacteria, 77,900,000 per cc.

TABLE 1.—*Analysis of pulp made from stock approved by visual inspection.*

| Sample.[1] | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| H 61a | Pulp, skin and core; fairly well sorted and made up promptly | O. K. | 9 | (3) | 16 |
| H 61b | .....do | O. K. | 11 | 17 | 12 |
| H 73b | Pulp, skin and core; well sorted and made up promptly | O. K. | 13 | 9 | 20 |
| H 77a | Pulp, whole tomatoes; sorted under personal supervision | O. K. | 5 | 7 | 4.5 |
| H 88 | Pulp, whole tomatoes; well washed and sorted | O. K. | 2 | 3 | 11 |
| H 89 | Pulp, skin and core; well washed and sorted | O. K. | 9 | 10 | 12 |
| H 90 | Pulp, whole tomatoes; well washed and sorted | O. K. | 5 | 4 | 5 |
| H 91 | Pulp, skin and core; well washed and sorted | O. K. | 15 | 8 | 15 |
| H 104 | Pulp, whole tomatoes; tomatoes ran good and then were sorted | O. K. | 2 | 5 | 5 |
| H 105 | .....do | O. K. | 2 | 5 | 7 |
| H 279 | Pulp, whole tomatoes; stock poor (many decayed), but well washed and sorted | O. K. | 6 | 3 | 6 |
| H 283 | .....do | O. K. | 6 | 14 | 12 |
| S 32 | Whole-tomato pulp | O. K. | 7 | 23 | 2 |
| S 44 | Whole-tomato pulp from cyclone | O. K. | 13 | 16 | 2 |
| S 45 | .....do | O. K. | 13 | 21 | 12 |
| S 54 | .....do | O. K. | 8 | 17 | 22 |
| S 57 | Whole-tomato pulp from cyclone; tomatoes sorted | O. K. | 11 | 8 | 8 |
| S 60 | .....do | O. K. | 8 | 12 | 6 |
| S 62 | .....do | O. K. | 12 | 8 | 6 |
| S 67 | .....do | O. K. | 3 | 5 | 10 |
| S 68 | Whole-tomato pulp from finisher; tomatoes sorted | O. K. | 7 | (3) | 8 |
| S 70 | Whole-tomato pulp; tomatoes sorted | O. K. | 12 | 9 | 4 |
| S 76 | Whole-tomato puree; tomatoes sorted | O. K. | 11 | 9 | 8 |
| S 77 | Whole-tomato pulp; tomatoes sorted | O. K. | 4 | 9 | 4 |
| S 79 | .....do | O. K. | 6 | 8 | 4 |
| S 81 | .....do | O. K. | 15 | 10 | 6 |
| S 85 | Whole-tomato puree from finisher | O. K. | 9 | 11 | 2 |
| S 87 | Whole-tomato pulp; tomatoes sorted and well washed | O. K. | 4 | 4 | 2 |
| S 88 | .....do | O. K. | 3 | 3 | ........ |
| S 95 | Whole-tomato pulp; tomatoes sorted | O. K. | 6 | 6 | 4 |
| S 97 | .....do | O. K. | 6 | 5 | 8 |
| S 99 | .....do | O. K. | 14 | 9 | 10 |
| S 107 | Whole-tomato pulp; indifferent sorting | O. K. | 4 | 10 | 10 |
| S 108 | .....do | O. K. | ........ | ........ | 14 |
| S 110 | Whole-tomato pulp; well sorted | O. K. | 6 | 2 | 8 |

[1] H, analyzed by B. J. Howard; S, analyzed by C. H. Stephenson.
[2] O. K., good, or acceptable.
[3] Very few.

Table 2 also serves to show that delay during the manufacture of pulp usually produces a rapid increase in the growth of organisms, noticeably yeasts and spores, or bacteria, or both, with the result that high counts are obtained for these organisms in the final product. This is well illustrated in Samples H 59, H 67, H 96a, and S 64. The absolute necessity of handling tomato products promptly in order to avoid secondary spoilage is shown in the case of Samples S 70 and S 78. Sample S 70 is the count on a sample of pulp freshly made, while Sample S 78 represents the same batch after standing 24 hours. The counts are:

| | S 70 | S 78 |
|---|---|---|
| Fields with molds (per cent) | 4 | 4 |
| Yeasts and spores (per 1/60 cmm) | 12 | 9 |
| Bacteria (million per cc.) | 9 | 218 |

TABLE 2.—*Analysis of pulp made from bad or questionable stock as determined by visual inspection.*

| Sample.[1] | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| H 57 | Puree, skin and core; very little sorting | C | 45 | (3) | 16 |
| H 58 | Pulp, skin and core; poorly sorted | C | 15 | (3) | 75 |
| H 59 | Pulp, skin and core; apparently well sorted but stock left in barrels Saturday to Tuesday | C | 162 | 240 | 10 |
| H 63 | Puree, skin and core; fairly well sorted and made up promptly | ? | 32 | 12 | 20 |
| H 67 | Pulp, skin and core; very imperfectly sorted, allowed to stand 3 or 4 hours before pulping | C | 60 | 192 | 67 |
| H 70 | Pulp, skin and core; very imperfectly sorted, allowed to stand 6 hours before pulping | C | 35 | 44 | 36 |
| H 73e | Pulp, skin and core; decayed condition, largely dry rot (laboratory experiment) | C | 61 | 48 | 100 |
| H 75b | Pulp, skin and core; indifferently sorted; allowed to stand 2 to 6 hours before pulping | C | 55 | 50 | 22 |
| H 76a | Pulp, whole tomatoes; fairly well sorted | ? | 7 | 5 | 5 |
| H 80a | Pulp, whole tomatoes; fairly well sorted but open to criticism; some decayed tomatoes | ? | 7 | 9 | 13 |
| H 81a | ....do | C | 18 | 12 | 17 |
| H 83a | Pulp, whole tomatoes; sorting open to strong criticism | C | 13 | 5 | 17 |
| [4] H 84c | Pulp, skin and core; sorting wholly inadequate | C | 63 | 60 | 100 |
| [4] H 85 | ....do | C | 114 | 120 | 92 |
| [4] H 86 | ....do | C | 150 | 84 | 100 |
| [4] H 87 | ....do | C | 155 | 84 | 100 |
| H 92 | Pulp, whole tomatoes; no sorting; washing not satisfactory | C | 21 | 5 | 44 |
| H 93 | ....do | C | 15 | 7 | 45 |
| H 94c | Pulp, whole tomatoes (gravity method); not sorted; too many damaged tomatoes | C | 18 | 7 | 32 |
| H 95a | Pulp, skin and core; sorting not wholly satisfactory (not promptly made up) | C | 20 | 12 | 30 |
| H 96a | Pulp, skin and core; prepared as 95a but left over night before pulping | C | 61 | 200 | 29 |
| H 97c | Pulp, skin and core; no sorting; bad conditions throughout; fairly prompt handling | C | 37 | 26 | 65 |
| H 98b | ....do | C | 72 | 43 | 90 |
| H 103a | Pulp, whole tomatoes; sorting unsatisfactory | C | 8 | 7 | 25 |
| H 106a | Pulp, whole tomatoes; not sorted, acknowledged by manufacturer to need sorting | C | 12 | 5 | 21 |
| [5] H 108a | Pulp, skin and core; not sorted; all refuse from tables used; bad | C | 17 | 7 | 26 |
| [5] H 109 | Pulp, skin and core; not sorted; all refuse from tables from day's accumulation kept hot until used | C | 27 | 19 | 19 |
| H 110b | Pulp, skin and core; all refuse with decayed parts from table used; bad | C | 13 | 36 | 40 |
| H 113a | Pulp, skin and core; all refuse from tables used; product condemned by employees | C | 36 | 20 | 85 |
| H 114a | ....do | C | 19 | 41 | 71 |
| H 273 | Pulp, skin and core; all refuse from tables used; no sorting; bad | C | 31 | 41 | 74 |
| H 274 | ....do | C | 35 | 36 | 65 |
| H 275 | ....do | C | 42 | 53 | 86 |
| H 276 | ....do | C | 53 | 52 | 87 |
| H 277 | ....do | C | 44 | 52 | 84 |
| S 22 | Pulp, skin and core; all refuse from table used; objectionable | C | 21 | 9 | 26 |
| S 23 | Skin and core pulp; tomatoes not sorted | C | 25 | 13 | 40 |
| S 24 | ....do | C | 66 | 24 | 42 |
| S 49 | Tomato pulp from unsorted tomato peelings | C | 61 | 66 | 37 |
| S 64 | Whole-tomato pulp, after standing 20 hours | C | 42 | 773 | 6 |
| S 78 | Whole-tomato pulp, after standing 24 hours | C | 9 | 218 | 4 |
| S 80 | Tomato waste from sorting tables made into pulp | C | 270 | 365 | 80 |
| S 102 | Skin and core pulp; no sorting of tomatoes | C | 21 | 28 | 45 |
| S 103 | Whole-tomato pulp; small tomatoes | ? | 16 | 21 | 26 |
| S 109 | Whole-tomato pulp; indifferent sorting | ? | ........ | ........ | 22 |

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[1] H, analyzed by B. J. Howard; S, analyzed by C. H. Stephenson.

[2] C, bad product from inspection of raw material; ?, doubtful or open to criticism.

[3] Very few.

[4] Taken at same plant at different times the same day.

[5] Very little washing of tomatoes at start; were fairly good, but some decayed.

### BARREL PULP.

Table 3 gives the counts obtained upon a number of samples of barrel pulp. The character of the stock from which these pulps were made is not known, beyond the fact that nearly all were skin and core pulps. The results, however, are of interest in comparison with the data in Tables 1 and 2. Table 3 brings out strongly the fact that in barrel stock the counts on yeasts and spores, and especially on bacteria, are usually very high. It also serves to explain the counts obtained on catsup made from barrel stock. In two instances the visual inspection of the barrel stock left a doubt as to whether the product was suitable for use, but such cases are rare. Excluding these two from the calculation, the averages of the counts on the remainder of the samples in this series are: Molds in 48 per cent of the fields; yeasts and spores, 77 per 1/60 cmm; bacteria, 207,700,000 per cc. The results in this table prove the inadvisability of trying to use barrels for storing tomato pulp.

Table 3.—*Analysis of pulp stored in barrels (condition of stock when made, not known.)*

| Sample.[1] | Description. | Character from inspection when opened.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| H 16 | Pulp in barrels, 7-9 months; odor of spoilage | C | 22 | 96 | 66 |
| H 17 | Pulp in barrels, 7-9 months; odor of spoilage; gas | C | 93 | 84 | 100 |
| H 20 | Pulp in barrels, 7-9 months; odor bad | C | 160 | 408 | 50 |
| H 22 | Pulp in barrels, 7-9 months; odor bad; gas | C | 52 | 168 | 98 |
| H 27 | do | C | 52 | 320 | 98 |
| H 28 | do | C | 122 | 340 | 33 |
| H 29 | do | C | 250 | 312 | (3) |
| H 32 | Pulp in barrels, 7-9 months; very strong odor; bad; gas | C | 45 | 144 | 40 |
| H 33 | Pulp in barrels, 7-9 months; odor bad | C | 42 | 264 | 50 |
| H 34 | Pulp in barrels, 7-9 months; odor mild for barrel pulp | (5) | 12 | 32 | 41 |
| H 35 | Pulp in barrels, 2 to 3 years; old; strong odor; skin and core | C | 70 | 216 | 50 |
| H 36 | Pulp in barrels, 7-9 months; strong odor | C | 130 | 228 | 40 |
| H 37 | Pulp in barrels, 7-9 months; strong odor; skin and core | C | 32 | 192 | 50 |
| H 38 | do | C | 21 | 180 | 33 |
| H 39 | Pulp in barrels, 7-9 months; odor of spoilage milder than usual; whole tomatoes | C | 10 | 120 | 14 |
| H 40 | do | C | 67 | 132 | (4) |
| H 41 | do | C | 56 | 120 | 50 |
| H 46 | Pulp in barrels, 7-9 months; odor of spoilage milder than usual; one of the best seen | (5) | 15 | 29 | (6) |

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[1] H, analyzed by B. J. Howard.
[2] C, bad product from inspection when opened.
[3] Few.
[4] Very few.
[5] Doubtful or open to criticism.
[6] Not determined.

### CATSUP.

The results of counts of catsups (Tables 4 and 5) show that a relationship similar to that found in the case of pulps exists between products made from acceptable stock and those from decayed material. The counts on the good stock catsups averaged: Molds in 9 per cent of the fields; yeasts and spores, 11 per 1/60 cmm; bacteria, 8,900,000 per cc. Table 5 includes some catsups made from stock of doubtful character in addition to those that were unquestionably bad. If the doubtful ones are excluded from the calculation and an average taken of the remainder, the following approximate figures are obtained: Mold in 50 per cent of the fields; yeasts and spores, 56 per 1/60 cmm; bacteria, 131,100,000 per cc. Attention should be called to the fact that the bacterial count was especially high because Sample H 284 was actively spoiling at the time of examination.

TABLE 4.—*Analysis of catsup made from stock approved by visual inspection.*

| Sample.[1] | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| H 77b | Catsup, whole tomatoes; sorted under personal supervision | O. K. | 12 | 12 | 12 |
| H 102b | Catsup, whole tomatoes; well sorted; made up promptly | O. K. | 5 | 2.5 | 13 |
| H 107b | Catsup, whole tomatoes; well sorted | O. K. | 10 | 7 | 9 |
| H 272 | Catsup, whole tomatoes; apparently good method used | O. K. | 15 | 14 | 12 |
| H 278 | Catsup, whole tomatoes; poor stock, but well washed and sorted | O. K. | 10 | 12 | 14 |
| H 280 | do | O. K. | 8 | 7 | 11 |
| H 281 | do | O. K. | 7 | 5 | 3 |
| H 283 | Catsup, whole tomatoes; tomatoes poor, many decayed when received; but well washed and sorted | O. K. | 19 | 16 | 14 |
| H 287 | do | O. K. | 10 | 12 | 11 |
| H 288 | do | O. K. | 16 | 21 | 10 |
| S 30 | Catsup taken from filler; made from sorted tomatoes | O. K. | 12 | 16 | 12 |
| S 31 | Catsup, whole tomatoes; tomatoes poor; many decayed when received; but well washed and sorted | O. K. | 11 | 10 | 6 |
| S 46 | Whole tomato catsup | O. K. | 10 | 14 | 14 |
| S 58 | Finished whole tomato catsup | O. K. | 12 | 5 | 10 |
| S 63 | Catsup sauce for beans | O. K. | 11 | 9 | 6 |
| S 69 | Finished whole tomato catsup; tomatoes sorted | O. K. | 8 | (3) | 0 |
| S 73 | do | O. K. | 6 | 3 | 10 |
| S 74 | do | O. K. | 14 | 8 | 5 |
| S 75 | do | O. K. | 7 | 4 | 4 |
| S 83 | do | O. K. | 9 | 8 | 10 |
| S 90 | Whole tomato catsup; tomatoes sorted | O. K. | 3 | 2 | 6 |
| S 94 | do | O. K. | 20 | 6 | 5 |
| S 98 | do | O. K. | 10 | 7 | 20 |
| S 104 | do | O. K. | 24 | 10 | 16 |
| S 105 | do | O. K. | 14 | 10 | 4 |
| S 106 | do | O. K. | 11 | 13 | 8 |

[1] H, analyzed by B. J. Howard; S, analyzed by C. H. Stephenson.
[2] O. K., acceptable from inspection of raw material.
[3] Very few.

TABLE 5.—*Analysis of catsup made from bad or questionable stock as determined by visual inspection.*

| Sample.[1] | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| H 71 | Catsup, skin and core; poorly sorted; not made up promptly; stock stood 1-6 hours | C | 89 | 240 | 21 |
| H 72c | Catsup, skin and core; pieces more or less decayed; not promptly made | C | 143 | 130 | 90 |
| H 76c | Catsup, whole tomatoes; fairly well sorted, but not fully approved | (3) | 22 | 15 | 20 |
| H 80b | Catsup, whole tomatoes; fairly well sorted, but not approved | (3) | 15 | 26 | 25 |
| H 81b | Catsup, whole tomatoes; sorting open to criticism; not effective | (3) | 20 | 24 | 34 |
| H 82b | Catsup, whole tomatoes; sorting carelessly done and ineffective | C | 34 | 17 | 52 |
| H 83b | do | C | 40 | 17 | 61 |
| H 103b | Catsup, whole tomatoes; imperfectly sorted; made up promptly | (3) | 13 | 12 | 37 |
| H 106b | Catsup, whole tomatoes; not sorted but needing it; made promptly, well washed | C | 19 | 7 | 36 |
| H 111c | Catsup, skin and core; conditions very bad, refuse of every kind used without sorting; gravity method | C | 55 | 91 | 81 |
| H 282 | Catsup, whole tomatoes; fairly well sorted and washed | (3) | 15 | 35 | 16 |
| H 284 | Catsup, from barrel; vigorously fermenting | C | 10 | 416 | 9 |

[1] H, analyzed by B. J. Howard.
[2] C, condemned in opinion of writers.
[3] In doubt and at least open to criticism.

### PRODUCTS MADE FROM PEELED STOCK.

A few counts on chili sauce are given in Table 6. The tomatoes used for this were a poor grade and required extensive trimming to remove the decayed material. The counts indicate how well this work was being done and what may be regarded as the upper limit for products made from peeled stock such as is used in chili sauce manufacture.

TABLE 6.—*Analysis of chili sauce.*[1]

| Sample. | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 160 cmm.* | *Million per cc.* | *Per cent.* |
| 72d | Poor raw material, well trimmed. (Catsup No. 72c made from trimming of these) | O. K. | 11 | 12 | 2.5 |
| 73a | Raw stock well sorted. (Trimmings made into pulp 73b) | O. K. | 4 | 2 | (3) |
| 73aa | Raw stock partly decayed, well trimmed | O. K. | 6 | 9 | (4) |
| 75a | From sorted tomatoes | O. K. | 1 | 5 | 2 |
| 84d | Stock. (Peeled tomatoes from which trimmings for pulp 84c was obtained) | O. K. | 6 | 5 | 9 |

[1] Analyses by B. J. Howard.

[2] O. K., acceptable from inspection of raw material.

[3] None in 58 fields.

[4] None in 39 fields.

These figures are rather high for canned peeled tomatoes. Well handled stock usually gives very low counts. Fermented stock or reprocessed swells as a rule show a marked increase in organisms other than molds. Molds occasionally develop, however, to a noticeable degree in sealed cans, although such instances are rare. One remarkable example of this character came to the notice of the bureau several years ago. A shipment of pulp in 5-gallon cans was condemned because masses of mold, some as large as a man's head, were found in a number of cans. The size of many of the masses precluded any possibility of their having been present at the time the cans were filled.

The bureau is sometimes asked whether it is advisable to sort raw stock intended for peeling, provided the trimmings are to be discarded. In answer to this question attention might be called to two or three of the chili sauce samples given in Table 6 and the products made from their trimmings. As commonly understood, chili sauce is made from peeled tomatoes handled as for canning. The skins, cores, and bad portions are supposed to be removed during peeling. Chili sauce, Sample 72d, was made from poor, rather badly decayed stock, which, however, was so well trimmed that it was acceptable. The same was true of the stock from which Sample 84d was made. The stock used for chili sauce, Sample 73a, while poor, was well sorted before being peeled. Although a comparison of these three samples shows the counts to be slightly lower in the case of the sorted stock, on the whole the advantage gained scarcely justifies making sorting a requirement on general stock if the peeled tomatoes are the only portions to be used. In these particular cases, the trimmings were used for other products. The following comparison of the counts on them is, therefore, of interest:

| | Fields with molds. | Yeasts and spores. | Bacteria. |
|---|---|---|---|
| | *Per cent.* | *Per 1/60 cmm.* | *Million Per cc.* |
| Catsup made from trimmings of tomatoes peeled for 72d | 90 | 143 | 130 |
| Pulp from trimmings of tomatoes peeled for 84d | 100 | 63 | 60 |
| Pulp from trimmings of well-sorted tomatoes peeled for 73a | 20 | 13 | 9 |

The contrast between the character of the first two and the last is a good illustration of the counts obtained on such types of products handled as these were.

## RELATION BETWEEN PERCENTAGE OF ROT AND MICROSCOPICAL COUNTS.

During the earlier investigations made upon tomato products the character of the stock was usually determined by means of visual inspection only. In later experiments the counts were made on products in which the amount of rot in the raw stock was determined by weight. These experiments were divided into two groups. One group of samples was prepared in the laboratory from stock of known character, while the other group consisted of inspected stock made in the factory. "Decayed" or "rotten" stock is taken to mean such portions as would appeal to the average intelligent housewife or consumer as being decayed or rotten and unfit or undesirable for food. For purposes of study of the molds the two groups are considered separately.

### MOLD COUNTS.

#### LABORATORY SAMPLES.

In tests conducted in the laboratory the amount of rot in the whole tomato was determined by cutting out and weighing the decayed portion and calculating the percentage. These portions were then mixed and pulped by rubbing through a 20-mesh sieve. In a few cases this procedure was modified by pulping the good and bad portions separately and then mixing them in the proportions desired. Experience has shown, however, that such a pulp is usually not quite as satisfactory to work with as the products normally manufactured because it is somewhat difficult to produce in the laboratory a pulp of just the same texture as that made under good factory conditions. The experiments and counts are nevertheless incorporated in this bulletin, because when compared with the counts on pulp made under factory conditions they show that the same general relationship between the percentage of rot and counts is maintained. The results obtained (Table 7) are tabulated in the order of increasing amounts of decay or rot present in the original stock. Samples containing 1 per cent or less of rot show low counts on each type of organism, while in those containing more than that amount one or another of the organisms usually runs higher than is the case in good stock.

TABLE 7.—*Relation between percentage of rot and microscopical count on laboratory samples.*

| Sample. | Rot, by weight, in stock. | Fields with molds. | Yeasts and spores. | Bacteria. | Sample. | Rot, by weight, in stock. | Fields with molds. | Yeasts and spores. | Bacteria. |
|---|---|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per 1/60 cmm.* | *Million per cc.* | | *Per cent.* | *Per cent.* | *Per 1/60 cmm.* | *Million per cc.* |
| 1 | 0 | 0 | 4 | 5 | 24 | 9.5 | 16 | 25 | 18 |
| 2 | 0 | 2 | 4 | 4 | 25 | 9.9 | 36 | 14 | 83 |
| 3 | 0 | 0 | 9 | 3 | 26 | 10.0 | 42 | 19 | 123 |
| 4 | 0 | 0 | 3 | 2 | 27 | 10.0 | 42 | 19 | 116 |
| 5 | 0 | 2 | 4 | 3 | 28 | 10.4 | 30 | 41 | 93 |
| 6 | 0 | 0 | 3 | 2 | 29 | 11.7 | 6 | 68 | 87 |
| 7 | 0 | 0 | 2 | 5 | 30 | 12.4 | 54 | 23 | 34 |
| 8 | 0 | 0 | 3 | 2 | 31 | 13.8 | 32 | 35 | 32 |
| 9 | 0 | 0 | 9 | 14 | 32 | 15.0 | 57 | 22 | 197 |
| 10 | 1 | 2 | 20 | 10 | 33 | 18.0 | 20 | 31 | 29 |
| 11 | 1.8 | 0 | 20 | 28 | 34 | 19.1 | 66 | 9 | 223 |
| 12 | 2 | 8 | 27 | 18 | 35 | 20.0 | 70 | 24 | 402 |
| 13 | 3 | 8 | 23 | 29 | 36 | 20.0 | 63 | 22 | 366 |
| 14 | 3.4 | 8 | 1 | 2 | 37 | 22 | 38 | 31 | 42 |
| 15 | 4 | 16 | 35 | 55 | 38 | 23.6 | 50 | 34 | 101 |
| 16 | 5 | 22 | 38 | 69 | 39 | 24.3 | 74 | 12 | 9 |
| 17 | 5 | 4 | 28 | 13 | 40 | 31 | 42 | 37 | 49 |
| 18 | 5 | 22 | 20 | 65 | 41 | 40 | 64 | 34 | 54 |
| 19 | 5.0 | 27 | 16 | 76 | 42 | 50.9 | 64 | 36 | 60 |
| 20 | 5.2 | 12 | 12 | 28 | 43 | 100.0 | 98 | 210 | 396 |
| 21 | 5.5 | 50 | 7 | 5 | 44 | 100.0 | 100 | 35 | 65 |
| 22 | 7.3 | 0 | 6 | 93 | 45 | 100.0 | 100 | 22 | 960 |
| 23 | 7.5 | 24 | 4 | 15 | 46 | 100.0 | 98 | 103 | 860 |

No high mold count occurs in samples low in amount of rot (Table 7). In some instances, however, low counts of mold were obtained in samples containing a substantial amount of rot. In such cases the decay was due principally to yeasts or bacteria, the count for one of which is usually high (Samples 18, 22, and 29). If, however, mold is the principal cause of decay, the counts on yeasts and bacteria are low (Samples 21 and 39).

In Figure 1 the mold counts have been plotted as ordinates and the percentage of rot in the stock as abscissas. Having plotted on the chart the mold counts in Table 7, it is possible by connecting the outlying points to define the approximate limits of what may be called the "Zone of Possible Mold Counts." From the chart it is seen that within this zone any count within certain limits may occur. In the writer's experience no counts on laboratory samples beyond these limits have been observed. For instance, no laboratory sample with less than 5.5 per cent of rot gave a mold count of more than 50. In making the chart the zone beyond 24.3 per cent of rot is represented on the basis of Samples 44 and 45, though the chart as drawn does not extend beyond the point of 30 per cent rot.

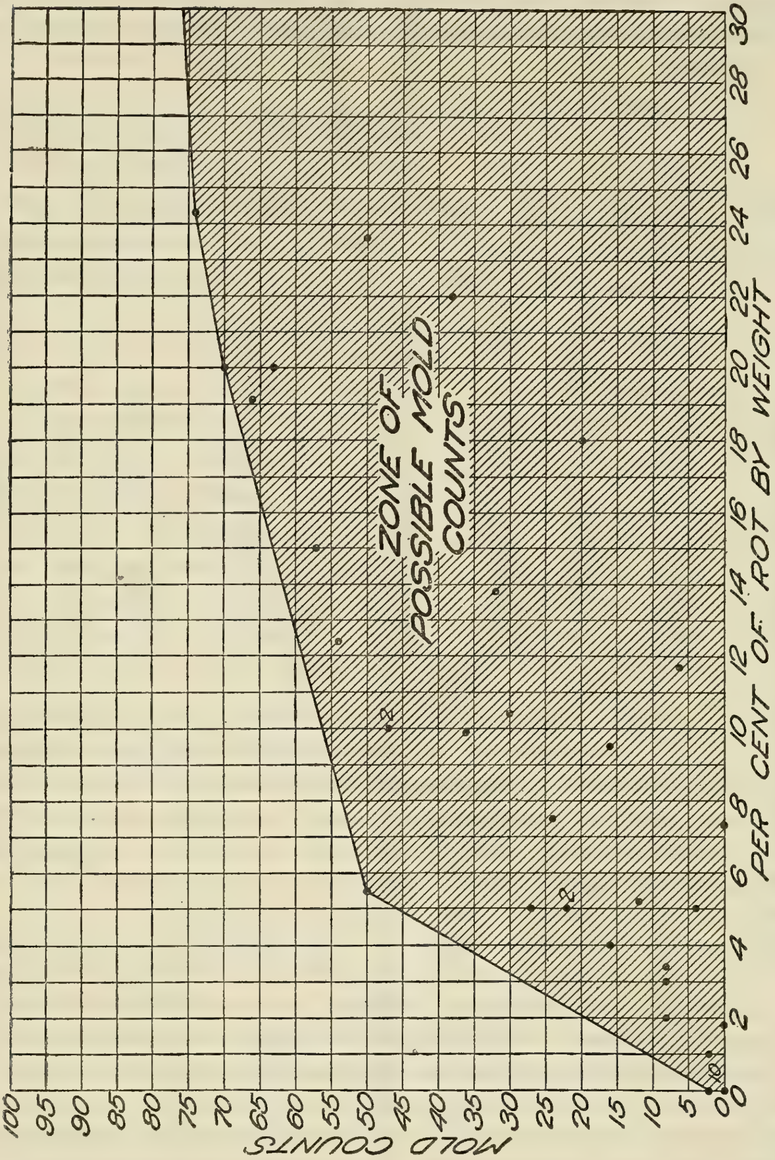

FIG. 1.—Relation between percentage by weight of rot and mold count (laboratory samples).

### FACTORY SAMPLES.

To obtain data on a practical manufacturing scale, tests under various factory conditions were conducted. In some of the plants the conditions were excellent, while in others they were highly objectionable. In making the tests the amount of decay was estimated or determined by weight as accurately as was practicable. With whole tomato stock it was usually customary to take a representative sample of from 25 to 50 pounds from the stream of sorted and washed stock on its way to the breaking-up tanks or to the cyclones. Each tomato in such a sample was inspected critically and the bad portions cut out and separated from the good portions. The parts thus separated were then weighed and the percentage of rotten or decayed material calculated. To estimate the amount of decay in the trimming pulps the amount of decayed material in the peeling stock was determined as in the case of the whole tomato stock. Since all the decayed material in the peeling stock is left in the trimmings, the percentage as determined on the scalded stock was multiplied by two. Although this may not be strictly accurate, it approximates the true figure nearly enough to be used as a practical working factor. It was adopted in calculating the data after tests had been conducted in various plants to determine what proportion of the stock sent to the peelers is left in the trimmings.

Field work performed during the last three seasons has demonstrated that with proper equipment and factory management there is no excuse for the stock which is ready for the cyclone to contain over 1 per cent of decayed material. Any excess is traceable to some fault in the system or to improper management.

TABLE 8.—*Relation between amount of rot and microscopical counts on tomato products, factory samples.*[1]

| Day. | Average rot, by weight, in stock. | Average fields with molds. | Average yeasts and spores. | Average bacteria. |
|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per 1/60 cmm.* | *Million per cc.* |
| 1 | 0.2 | 5 | 9 | 9 |
| 2 | 0.2 | 6 | | |
| 3 | 0.3 | 7 | | |
| 4 | 0.4 | 13 | | |
| 5 | 0.4 | 7 | 6 | 9 |
| 6 | 0.5 | 5 | | |
| 7 | 0.5 | 9 | | |
| 8 | 0.5 | 21 | | |
| 9 | 0.5 | 11 | 3 | 5 |
| 10 | 0.6 | 21 | | |
| 11 | 0.8 | 16 | 4 | 9 |
| 12 | 0.8 | 24 | 8 | 15 |
| 13 | 0.8 | 18 | 14 | 10 |
| 14 | 0.9 | 19 | 11 | 9 |
| 15 | 0.9 | 20 | 13 | 7 |
| 16 | (2) | 9 | | |
| 17 | (2) | 14 | | |
| 18 | 1.0 | 2 | 2 | 8 |
| 19 | 1.0 | 8 | 5 | 6 |
| 20 | 1.0 | 12 | | |
| 21 | 1.0 | 20 | | |
| 22 | 1.2 | 13 | 4 | 6 |
| 23 | 1.4 | 13 | | |
| 24 | 1.8 | 9 | 7 | 9 |
| 25 | 1.9 | 29 | | |
| 26 | 2.0 | 13 | | |
| 27 | 2.1 | 24 | | |
| 28 | 2.2 | 16 | | |
| 29 | 2.4 | 16 | | |
| 30 | 3.2 | 35 | | |
| 31 | 3.2 | 50 | | |
| 32 | 3.8 | 38 | 13 | 14 |
| 33 | 3.8 | 17 | | |
| 34 | 4.0 | 41 | 16 | 14 |
| 35 | 4.0 | 60 | | |
| 36 | 6.0 | 32 | 11 | 11 |
| 37 | 7.8 | 49 | | |
| 38 | 9.8 | 72 | | |
| 39 | 20.0 | 87 | 64 | 156 |

[1] Summary of all determinations on similar products made on same day.

[2] Under 1.0.

Table 8 summarizes 39 days' work under factory conditions on the relation between the amount of rot and the microscopical counts. As in Table 7, the results are arranged in the order of the amount of decayed material in the original stock. Under factory conditions it is frequently difficult to trace a definite portion of raw stock through the whole process of manufacture, with any certainty that the final product is from the same stock, unmixed with other lots. It has therefore been considered advisable to average the daily results obtained on the amount of rot and compare them with corresponding daily averages on the microscopic tests. It might be stated in this connection that the results thus summarized in Table 8 represent experiments conducted in 17 different factories and involve 179 determinations of percentage by weight of rot in stock and 235 mold counts.

Experience has shown that in factories where good, thorough washing is employed and where promptness of handling is observed the mold count is of greater importance in judging the condition of the raw stock than the counts on the other organisms. High yeast and spore, and bacterial counts usually indicate secondary spoilage. In order to secure as large a mass of data as possible on the mold content, complete counts for the other organisms were made in only a few cases during the field work of 1916. Hence the blanks in the table. A comparison of the field results shows that, as in the case of the laboratory tests, high mold counts were not found in the products made from stock which had been well handled and sorted.

The results given in Table 8 emphasize two points also brought out in Table 7: First, none of the samples having 1 per cent or less of rot give excessively high microscopical counts; second, with increasing amounts of rot more or less increase in one or another of the microorganisms occurs. They also show that while a comparatively low count may not always indicate a product made from suitable stock, it is clearly demonstrated that a high count on any one or more of the three types of organisms indicates bad stock. It appears, then, that one weak spot in the micro-counting system is its failure to disclose some bad products which should be condemned.

To facilitate the study, the mold counts given in Table 8 have been plotted graphically in Figure 2, in which the "Zone of Possible Mold Counts" is indicated by the shaded portion. Attention should be called to the fact that beyond 20 per cent of rot the chart is plotted on the basis of the assumption that 100 per cent rot would give a mold count of 100 per cent of the fields. As a matter of fact, the mold count reaches this maximum of 100 per cent of the fields with less than this amount of rot, as will be seen by reference to the laboratory series. These high counts, while occurring occasionally in commercial samples, are now rare. In the studies of the relationship

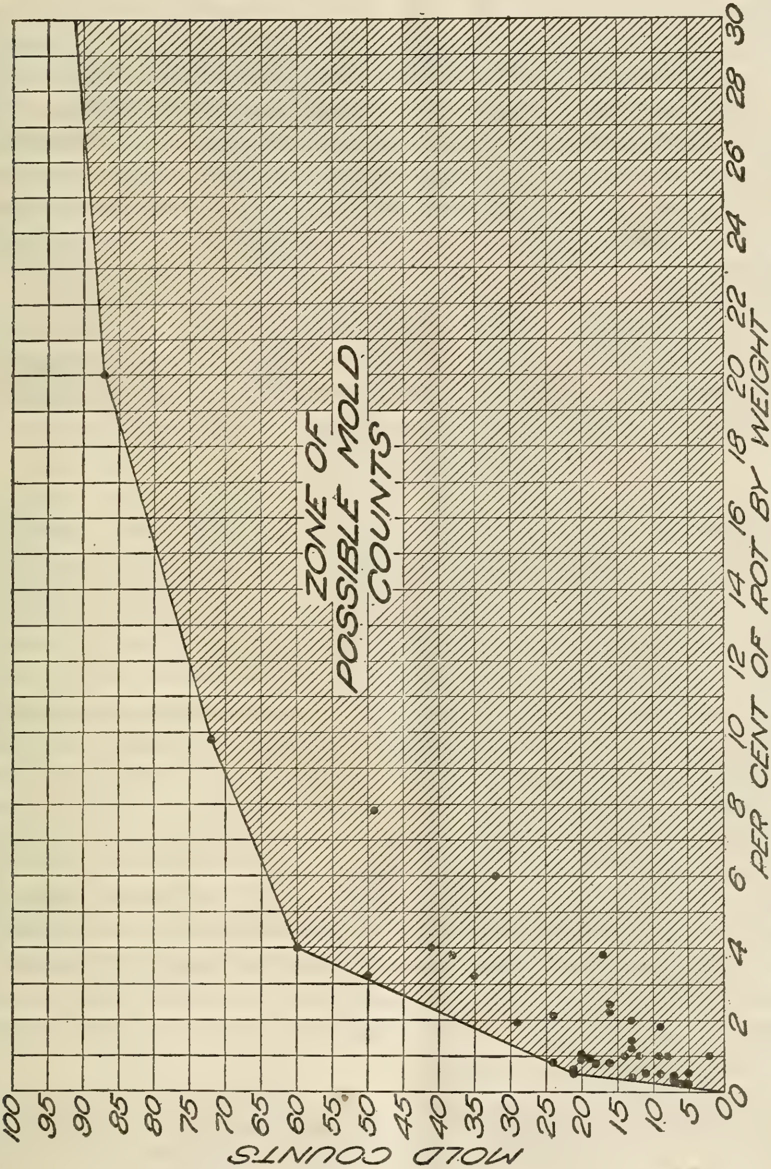

Fig. 2.—Relation between percentage by weight of rot and mold count (factory samples).

between rot and count under factory conditions, 20 per cent of rot was the highest on which the full data were secured. From 0 to ½ per cent of rot the mold count rises sharply. Beyond ½ per cent the rate of rise gradually decreases, until after 20 per cent of rot the rate of increase is slow. On the whole, the zone was higher on factory than on laboratory samples. The chart shows that a count of 60 per cent molds represents a rot content of not less than about 4 per cent. It is interesting to note that the mold count of 25, which was suggested as a factory working basis in 1911, represents at least 0.8 to 0.9 per cent of rot. There may be more rot than that present, but, on the basis of the data at hand, it is highly improbable that it represents less than that amount. From the chart it is possible to calculate the approximate minimum percentage of decay represented by a given mold count. Thus, for instance, a mold count of 40 enters the "Zone of Possible Mold Counts" at a point representing 2.2 per cent of decay. Therefore a count of 40 may be obtained in samples having any amount of rot between 2.2 and 100 per cent.

### SPORE AND YEAST COUNTS.

As has been pointed out, such a degree of efficiency in washing and sorting may be maintained in good factory practice that the percentage of decay in stock will be 1 per cent or less. With this in mind, an examination of Tables 7 and 8 shows that on samples containing such amounts of objectionable material the counts on yeasts and spores are 20 or less per 1/60 cmm. In the majority of the samples the comparatively low numbers of this type of organisms are noteworthy. This fact serves to emphasize what has already been stated, that high counts of these organisms are more frequently an indication of secondary than of primary spoilage. Thus in the factory series of samples (Table 8), which includes those having large amounts of decay, only one sample high in these organisms is found. In this case (Sample 39) it was trimming stock and was not made up as promptly as it should have been; consequently a certain amount of secondary spoilage had occurred. The estimate of 20 per cent rot is therefore under rather than over the true amount. All of the other factory samples were handled in such a way as to prevent appreciable secondary spoilage.

The combined results of yeast and spore counts, both on laboratory (Table 7) and factory tests (Table 8), have been plotted in Figure 3. Here it is seen that up to a count of 10 the results may be regarded as negligible. A count of 20 represents about 1 per cent of decay. From this point the rate of increase is slower. As in the case of molds, the rule that a moderately low yeast and spore count may not always indicate good stock but does indicate at least a certain amount of rot, holds good for this class of organisms. It is also

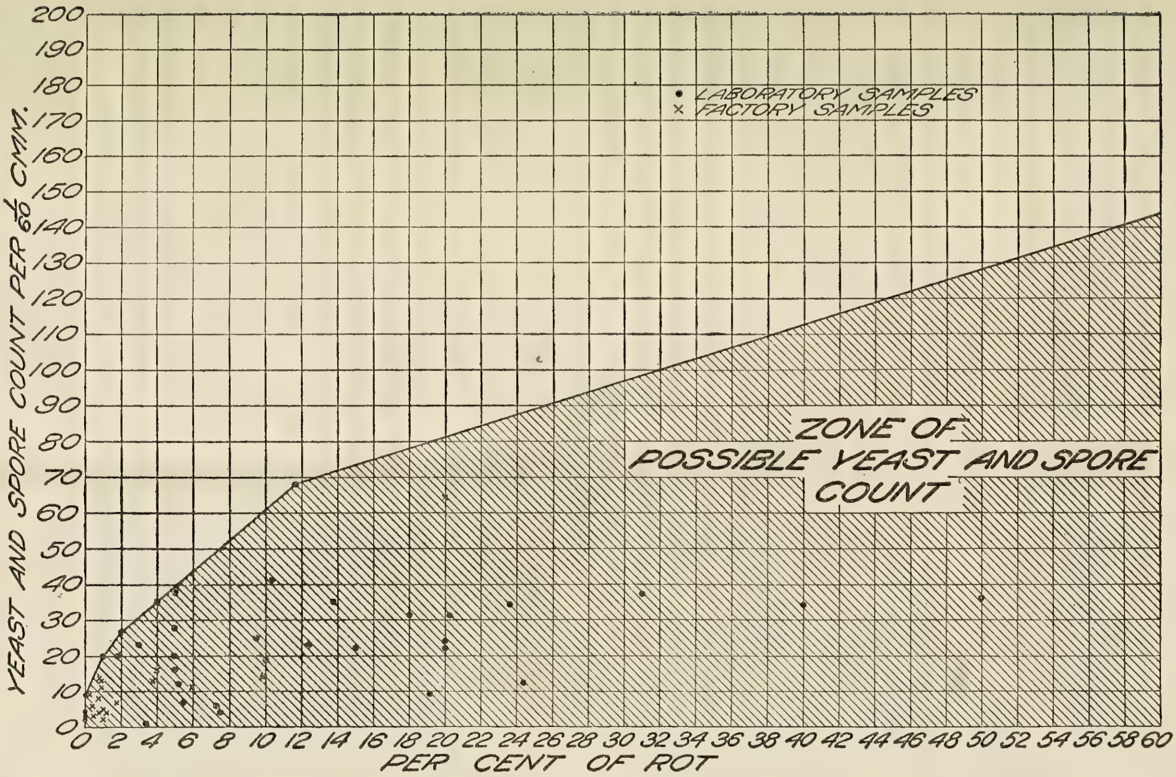

Fig. 3.—Percentage by weight of rot, and yeast and spore count. (The line showing the upper limit of "Zone of Possible Yeast and Spore Count" beyond 12 per cent of rot is based on sample 46, Table 7).

shown that high counts invariably indicate bad stock. From the chart it appears then that a count of 35 yeasts and spores in a unit volume may indicate 4 per cent or more of decayed material. By connecting the outlying points in the chart, the upper limits of the "Zone of Possible Yeast and Spore Counts" are obtained. The limit of the zone shown beyond 12 per cent of rot has been based on the count for laboratory Sample 46. From such a chart it is possible to calculate the minimum percentage of rot which a certain count represents.

### BACTERIAL COUNTS.

Considering now the counts of bacteria in Tables 7 and 8, it is found that in the samples with 1 per cent or less of rot the count on bacteria is relatively low. With greater amounts of rot more bacteria may be found, till in Sample 45 a count of nearly a billion was obtained. In this case there was also a maximum mold count (100 per cent). Comparing the results in Table 7 with those in Table 8 it is noted that the mold count runs up more rapidly in the factory than in the laboratory series. With yeasts and spores and with bacteria, however, the reverse is true, that is, the counts mount more rapidly in the laboratory series. This is explained by the fact that in the laboratory series the tomatoes had not been subjected to the mechanical or factory method of washing, which results in eliminating much of the soft rot wherein these organisms are most abundant. The decay which resists this washing process is more commonly due to molds. The other organisms when present are usually, though not always, the result of secondary infection, and produce some of the very soft types of decay.

The results of bacterial counts on the laboratory and factory samples, tabulated in Tables 7 and 8, have been plotted in Figure 4. Below 15,000,000 bacteria the results indicate little as to the amount of decay, but above this point, up to about 20 per cent of rot, the ratio of increase as shown on the chart is about 20,000,000 for each per cent of rot. Beyond 20 per cent of rot the upper limit of the zone is based on the count on Sample 45 (Table 7). As in each of the other charts, the rule holds true here that a low bacterial count does not necessarily indicate sound stock, but a high bacterial count always indicates bad stock.

### MICROSCOPIC COUNTS ON TOMATO SAUCES AND PASTES.

Tomato sauce and paste are practically the same kind of product as tomato pulp, but concentrated to a much greater degree. Hitherto no opinion has been published by the Bureau of Chemistry concerning the microscopic counts obtained on the more highly concentrated tomato products, when handled in accordance with good factory practice. During the season of 1912 a study of these products was

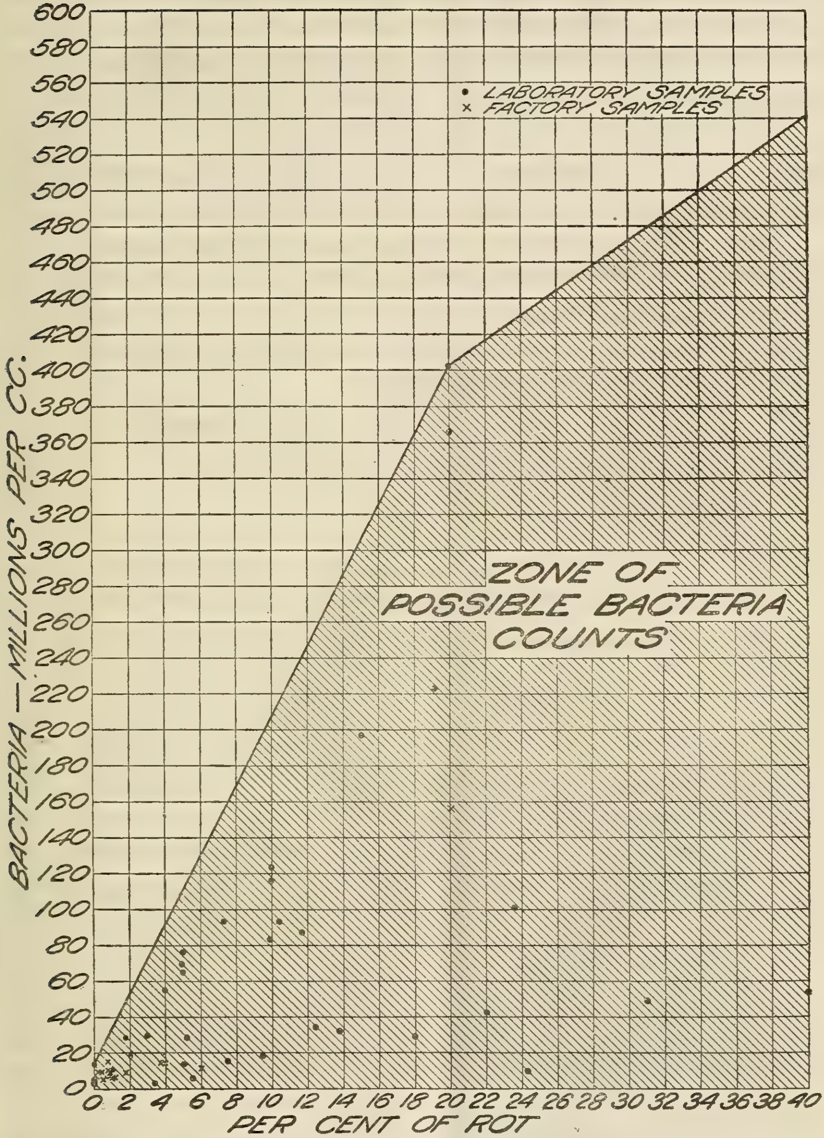

FIG. 4.—Percentage by weight of rot and bacterial count. (The line showing the upper limit of "Zone of Possible Bacteria Counts" beyond 20 per cent of rot is based upon the count on sample 45, Table 7),

made under factory conditions in Italy. These studies included investigation into the conditions of manufacture in each of the important tomato-producing sections of that country. In many of the factories experimental work was conducted. Tables 9 to 12 have been compiled from the data thus collected.

TABLE 9.—*Analysis of Italian tomato pulp made from stock approved by visual inspection.*[1]

| Sample. | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| 519 | From freshly delivered tomatoes | O. K. | 7 | 14 | 5 |
| 521 | .....do | O. K. | 5 | 3 | 5 |
| 524 | From fresh tomatoes | O. K. | 5 | (3) | 8 |
| 528a | From freshly delivered tomatoes | O. K. | 5 | 10 | 11 |
| 529 | .....do | O. K. | 5 | 7 | 18 |
| 530 | .....do | O. K. | 3 | 14 | 8 |
| 539a | .....do | O. K. | 8 | 7 | 9 |
| 548a | Made under personal supervision from freshly delivered tomatoes; washed but not sorted | O. K. | 6 | 5 | 7 |
| 552a | From freshly delivered tomatoes; controlled experiment; washed but not sorted | O. K. | 16 | 10 | 4 |
| 555a | From freshly delivered tomatoes; washed but not sorted | O. K. | 11 | 5 | 2 |
| 596 | From approved trimmings; controlled factory test | O. K. | 3 | 5 | 1 |
| 602 | Made under personal supervision from acceptable trimmings | O. K. | 8 | 4 | 11 |

[1] Analyses by B. J. Howard. [2] O. K., acceptable from inspection of raw material. [3] Very few.

TABLE 10.—*Analysis of Italian tomato pulp made from bad or questionable stock as determined by visual inspection.*[1]

| Sample. | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| 523 | From trimmings not made up promptly; fermenting | C | 56 | 110 | 4 |
| 540a | From tomatoes stored in bin 48 hours; very sour and moldy; no washing or sorting | C | 253 | 96 | 69 |
| 542 | From tomatoes stored in bin about 54 hours; very sour and moldy; no washing or sorting | C | 305 | 132 | 100 |
| 543a | .....do | C | 275 | 115 | 20 |
| 545a | From tomatoes stored in bin 3 or 4 days with 50 per cent fresh tomatoes | C | 200 | 250 | 30 |
| 546 | From tomatoes stored in bin 24 hours; in bad condition | C | 164 | 53 | 44 |
| 549 | From tomatoes washed and stored about 8 hours in bin; not acceptable | C | 24 | 22 | 20 |
| 551a | From tomatoes stored in baskets; sour and moldy | C | 136 | 25 | 31 |
| 553 | From tomatoes stored in baskets 24 to 48 hours; bad condition | C | 177 | 60 | 36 |
| 558 | From tomatoes bin-stored, sour and moldy | C | 169 | 43 | 19 |
| 573 | From trimmings, waste and bad tomatoes | C | 163 | 72 | 47 |
| 575 | From trimmings obtained from peeling tables; not acceptable | C | 131 | 58 | 63 |
| 577 | From decayed tomatoes | C | 175 | 72 | 76 |
| 578 | .....do | C | 350 | 240 | 80 |
| 579 | From trimmings taken promptly from tables but not of acceptable character | C | 20 | 10 | 25 |
| 580 | From trimmings allowed to stand 4 or 5 hours before pulping | C | 85 | 60 | 24 |
| 592 | From trimmings from fresh tomatoes, but delayed in pulping | C | 31 | 45 | 19 |
| 595 | From whole tomatoes; many decayed | C | 50 | 50 | 60 |
| 617 | From partly decayed stock | C | 110 | 30 | 42 |
| 622 | .....do | C | 170 | 25 | 44 |

[1] Analyses by B. J. Howard. [2] C, condemned; bad product from inspection of raw material.

Table 9, which gives the data on the unconcentrated juice, shows that on acceptable stock, as determined from visual inspection, the counts were low, ranging no higher than on American stock. The average counts on these samples are: Molds, 8 per cent of the microscopic fields; yeasts and spores, 8 per 1/60 cmm.; bacteria, 7,500,000 per cc. On the other hand, Table 10 shows the counts on unconcentrated pulps from bad or questionable stock. In this case there is a marked increase in the number of organisms, especially of yeasts and spores and bacteria over that found to occur in sound stock. Hence it is reasonable to conclude that with proper control over the manufacturing processes Italian products should be fully equal to American products made under similar conditions. The finished product is on an average 2 or 2½ times more concentrated than standard pulp. Table 11 shows that the molds do not exceed 25 per cent of the fields, or the counts obtained on normal pulp. On good stock the upper limit for yeasts and spores appears to be about 50 per 1/60 cmm., while for bacteria it is about 40 million per cc. In other words, the mold count does not seem to be much higher than that on the pulp, while the increase in the count for yeasts, spores, and bacteria is more nearly proportional to the degree of concentration. Examination of counts on the sauces and pastes made from objectionable stock as determined by visual inspection (Table 12) shows that as a class they run particularly high in yeasts and spores and bacteria and are also rather high in molds. The average of these counts, excluding the questionable samples, is: Molds, 57 per cent of the fields; yeasts and spores, 511 per 1/60 cmm.; bacteria, 285,300,000 per cc. The contrast between these counts and those in Table 11 shows clearly the effect of sanitary methods on the character of the product.

TABLE 11.—*Analysis of Italian tomato sauces made from acceptable or fairly acceptable stock.*[1]

| Sample. | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| 520 | From freshly delivered tomatoes; made up promptly | O. K. | 24 | 12 | 15 |
| 528b | ....do | O. K. | 25 | 38 | 18 |
| 531 | ....do | O. K. | 40 | 40 | 12 |
| 532 | ....do | O. K. | 46 | 28 | 15 |
| 536 | ....do | O. K. | 48 | 24 | 12 |
| 538 | ....do | O. K. | 32 | 40 | 11 |
| 539b | From freshly delivered tomatoes | O. K. | 46 | 23 | 14 |
| 548b | From freshly delivered tomatoes; washed but not sorted; fairly good stock | O. K. | 51 | 31 | 22 |
| 561 | Made under personal supervision from fresh tomatoes | O. K | 40 | 25 | 4 |

[1] Analysis by B. J. Howard.

[2] O. K., acceptable from inspection of raw material.

Investigation showed the following to be the principal causes for high counts of microorganisms in tomato pastes: (*a*) Partly decayed stock imperfectly washed or sorted; (*b*) delay at some stage in the manufacturing process, allowing secondary spoilage to occur; and (*c*) the use of "swells" or spoiled "half stock" ("ministrella"). The particular condition causing the spoilage can sometimes be established in the finished product by microscopical examination. Sharp distinctions, however, can not at this stage of the investigations be drawn in every case.

TABLE 12.—*Analysis of Italian tomato sauces made from bad or questionable stock as determined by visual inspection.*[1]

| Sample. | Description. | Character from inspection.[2] | Yeasts and spores. | Bacteria. | Fields with molds. |
|---|---|---|---|---|---|
| | | | *Per 1/60 cmm.* | *Million per cc.* | *Per cent.* |
| 500 | From bin-stored tomatoes in bad condition | C | 1,120 | 466 | 96 |
| 501 | From partly decayed stock | C | 843 | 233 | 65 |
| 502 | From tomatoes not washed or sorted; of doubtful character | (3) | 114 | 92 | 24 |
| 503 | From tomatoes not washed or sorted; not approved. | C | 315 | 200 | 11 |
| 516 | From tomatoes not approved | C | 160 | 72 | 14 |
| 517 | From freshly delivered, but not washed, tomatoes | (3) | 54 | 30 | 3 |
| 526 | From tomatoes stored in bin overnight; partly decayed | C | 440 | 200 | 38 |
| 527 | From tomatoes held overnight in bin; objectionable conditions | C | 230 | 96 | 39 |
| 534 | From tomatoes stored in bin overnight; partly decayed | C | 340 | 96 | 43 |
| 540b | From tomatoes stored in bins from Saturday till Monday; bad condition | C | 900 | 360 | 100 |
| 545b | From tomatoes stored in bins 3 or 4 days; 50 per cent of fresh tomatoes added | C | 1,200 | 700 | 60 |
| 547 | From tomatoes stored in bin 24 hours; bad condition. | C | 750 | 290 | 60 |
| 550 | From tomatoes not approved because of handling system | C | 300 | 72 | 27 |
| 551b | From basket-stored tomatoes; rather sour and moldy | C | 700 | 115 | 56 |
| 559 | From bin-stored tomatoes; sour and moldy | C | 218 | 108 | 31 |
| 562a | From trimmings allowed to stand; bad condition | C | 580 | 1,250 | 72 |
| 574 | From trimmings; bad condition | C | 600 | 300 | 72 |
| 576 | From trimmings and bad tomatoes | C | 650 | 300 | 88 |
| 586 | From partly decayed tomatoes | C | 400 | 400 | 88 |
| 597 | From tomatoes, many decayed | C | 120 | 125 | 80 |
| 598 | .....do | C | 240 | 108 | 70 |
| 600 | .....do | C | 220 | 96 | 55 |
| 601 | From objectionable trimmings | C | 550 | 400 | 30 |
| 604 | From partly decayed stock | C | 375 | 200 | 54 |

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[1] Analyses by B. J. Howard.

[2] C, condemned; bad product from inspection of raw material.

[3] Doubtful, or open to criticism.

The influence of improper storage and handling of stock is illustrated by two tests run the same day at one of the plants visited. Sample A was taken from tomatoes stored in a bin overnight and not sorted or washed before being made into sauce. Sample B was a sauce made at the same plant the same day as A but came from good stock promptly handled.

| Sample. | Mold count. | Yeast and spore count. | Bacterial count. |
|---|---|---|---|
| A | 43 | 340 | 96 |
| B | 12 | 48 | 24 |

Thus it is seen that high counts on this class of products, as well as on those less concentrated, indicate bad stock or insanitary handling.

## METHOD FOR MICROANALYSIS OF TOMATO PRODUCTS.

Since the publication of Bureau of Chemistry Circular 68 no statement of the microscopical method used by the department has been issued. The bureau has received repeated requests for a restatement of the method, including more definite details of manipulation than were given in the circular. In 1915, after the method incorporating the most important of these details had been rewritten, the Association of Official Agricultural Chemists adopted it as a tentative method and published it November, 1916, in the Journal of the Association of Official Agricultural Chemists. At the meeting of the same association in November, 1916, a few minor changes were authorized. As it is uncertain when the association will publish the method in its amended form, permission has been granted by the chairman of the Board of Editors of the Association of Official Agricultural Chemists to incorporate it here.

### 49[1] APPARATUS.

(*a*) *Compound microscope.*—Equipped with apochromatic objectives and compensating oculars, giving magnifications of approximately 90, 180, and 500 diameters. These magnifications can be obtained by the use of 16 and 8 mm Zeiss apochromatic objectives with X6 and X18 Zeiss compensating oculars, or their equivalents, such as the Spencer 16 and 8 mm apochromatic objectives with Spencer X10 and X20 compensating oculars, the drawtube of the microscope being adjusted as directed below.

(*b*) *Thoma-Zeiss blood counting cell.*[2]

(*c*) *Howard mold counting cell.*—Constructed like a blood-counting cell but with the inner disk (which need not be ruled) about 19 mm in diameter.[2]

### 50[1] MOLDS (TENTATIVE).

Clean the special Howard cell so that Newton's rings are produced between the slide and the cover glass. Remove the cover and place, by means of a knife blade or scalpel, a small drop of the sample upon the central disk; spread the drop evenly over the disk and cover with the cover glass so as to give an even spread to the material. It is of the utmost importance that the drop be mixed thoroughly and spread evenly; otherwise the insoluble matter and consequently the molds are most abundant at the center of the drop. Squeezing out of the more liquid portions around the margin must be avoided. In a satisfactory mount Newton's rings should be apparent when finally mounted and none of the liquid should be drawn across the moat and under the cover glass.

Place the slide under the microscope and examine with a magnification of about 90 diameters and with such adjustment that each field of view represents approximately 1.5 sq. mm of area on the mount.[3] This area is of vital importance and may be obtained by adjusting the drawtube to the proper length as determined by actual measurement of the field, a 16 mm Zeiss apochromatic objective with a Zeiss X6 compensating ocular or a Spencer 16 mm apochromatic objective with a Spencer X10 compensating ocular, or their equivalents, being used to obtain the proper magnification.

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[1] These numbers refer to the sections as given in the Journal of the Association of Official Chemists, November, 1916.

[2] Comment by authors: In using these cells the plane parallel cover glasses furnished with them by maker should be used instead of the ordinary microscope cover glasses, since the latter are subject to curvatures that introduce errors in the thickness of the mounts.

[3] Comment by authors: In order to have an area of 1.5 sq. mm the diameter of the microscopic field should be 1.382 mm. This is determined by using a stage micrometer and adjusting the length of the microscope drawtube. Obviously after the proper drawtube length has been secured that adjustment should be noted and always used in making mold counts.

Observe each field as to the presence or absence of mold filaments and note the result as positive or negative. Examine at least 50 fields, prepared from 2 or more mounts. No field should be considered positive unless the aggregate length of the filaments present exceeds approximately one-sixth of the diameter of the field. Calculate the proportion of positive fields from the results of the examination of all the observed fields and report as percentage of fields containing mold filaments.

### 51[1] YEASTS AND SPORES (TENTATIVE).

Fill a graduated cylinder with water to the 20 cc mark, and then add the sample till the level of the mixture reaches the 30 cc mark. Close the graduate, or pour the contents into an Erlenmeyer flask, and shake the mixture vigorously 15 to 20 seconds. To facilitate thorough mixing the mixture should not fill more than three-fourths of the container in which the shaking is performed. For tomato sauce or pastes or products running very high in the number of organisms, or of heavy consistency, 80 cc of water should be used with 10 cc or 10 grams of the sample. In the case of exceptionally thick or dry pastes it may be necessary to make an even greater dilution.

Pour the mixture into a beaker. Thoroughly clean the Thoma-Zeiss counting cell so as to give good Newton's rings. Stir thoroughly the contents of the beaker with a scalpel or knife blade, and then, after allowing to stand 3 to 5 seconds, remove a small drop and place upon the central disk of the Thoma-Zeiss counting cell and cover immediately with the cover glass, observing the same precautions in mounting the sample as given under 50. Allow the slide to stand not less than 10 minutes before beginning to make the count. Make the count with a magnification of about 180 to obtain which the following combinations, or their equivalents, should be employed: 8 mm Zeiss apochromatic objective with X6 Zeiss compensating ocular, or an 8 mm Spencer apochromatic objective with X10 Spencer compensating ocular with draw tube not extended.

Count the number of yeasts and spores [2] on one-half of the ruled squares on the disk (this amounts to counting the number in 8 of the blocks, each of which contains 25 of the small ruled squares). The total number thus obtained equals the number of organisms in 1/60 cmm if a dilution of 1 part of the sample with 2 parts of water is used. If a dilution of 1 part of the sample with 8 parts of water is used the number must be multiplied by 3. In making the counts the analyst should avoid counting an organism twice when it rests on a boundary line between 2 adjacent squares.

### 52[1] BACTERIA (TENTATIVE).

Estimate the bacteria from the mounted sample used in 51, but allow the sample to stand not less than 15 minutes after mounting before counting. Employ a magnification of about 500, which may be obtained by the use of an 8 mm Zeiss apochromatic objective with an X18 Zeiss compensating ocular with draw tube not extended, or an 8 mm Spencer apochromatic objective with an X20 Spencer compensating ocular with a tube length of 190, or their equivalents. Count and record the number of bacteria in a small area consisting of 5 of the small-sized squares. Move the slide to another portion of the field and count the number on another similar area. Count 5 such areas, preferably 1 from near each corner of the ruled portion of the slide and 1 from near the center. Determine the average number of bacteria per area and multiply by 2,400,000, which gives the number of bacteria per cc. If a dilution of 1 part of the sample with 8 parts of water instead of 1 part of the sample with 2 parts of water is used in making up the sample, then the total count obtained as above must be multiplied by 7,200,000. Omit the micrococci type of bacteria in making the count.

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[1] These numbers refer to the sections as given in the Journal of the Association of Official Chemists, November, 1916.

[2] Comment by authors: The organisms counted as "yeasts and spores" are the yeast cells, and yeast and mold spores, not bacteria spores.

## EXPLANATION OF CALCULATIONS.

Figure 5 has been prepared to make somewhat clearer the explanation of the areas denoting the yeast and spore and bacterial counts. The light lines in the figure show the arrangement of rulings on the entire slide. The squares (A, A, etc.) and rectangles (B, B, etc.) designated in the figure by the heavy lines indicate the portions used for the yeast and spore and for the bacterial counts, respectively. The 8 large squares, A, A, etc., are the squares used for yeast and spore counts. Each of these squares has 25 of the small squares. The sum of the organisms counted in the 8 squares marked A, A, etc., is the number in 1/60 cmm. if a dilution of one part of product to two parts of water is used.

*Yeast and spore count.*—The ruled square on the slide is 1 mm on each side and the cell is 1/10 mm deep. The volume of the ruled part is therefore 1/10 cmm. The ruled area is divided into 16 large squares and the number of organisms is counted in 8 of these, which is equivalent to 1/2 of 1/10 cmm, or 1/20 cmm. If a dilution of one part of the product to two parts of water is used 1/3 of 1/20 cmm, or 1/30 cmm as representing the actual amount of original stock in which organisms are counted, is obtained.

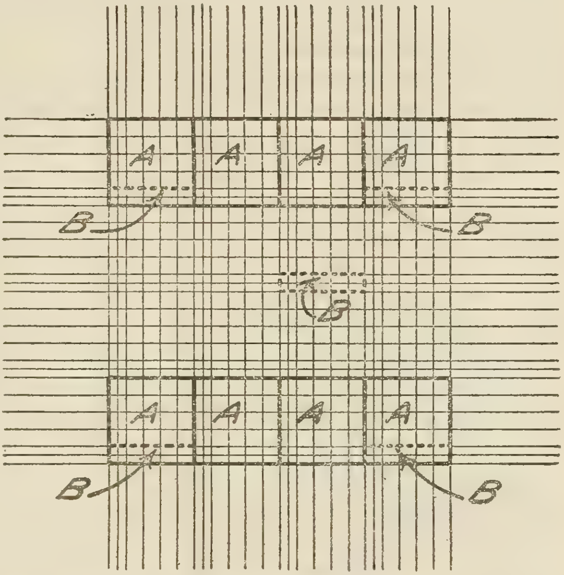

FIG. 5. Diagram of Thoma rulings. One millimeter divided by lines into 20 spaces in each direction, each space equaling 1/20 mm. To facilitate counting, every fifth space is subdivided by a line through the middle.

*Bacterial count.*—The rectangles, B, B, etc., each including 5 of the smallest squares, represent the areas, used in making the bacterial count. Similar rectangles of equal area might be selected, the object being to count 5 such areas well distributed over the ruled portion of the slide. The *average* number of bacteria counted on 5 rectangles, such as B, B, etc., multiplied by 2.4 million, equals the number of bacteria per cubic centimeter. In calculating the bacteria, it is observed that there are 400 (20×20) small squares on the slide. The number of bacteria in rectangles (B, B, etc.), each containing 5 of these small squares, are counted and an average made. This average represents the bacteria in 1/80 of the total ruled area. Since the cell is 1/10 mm deep, the volume represented by the organisms counted is 1/80×1/10, or 1/800 cmm. With the usual dilution of one part of product to two parts of water the actual volume in which the number of organisms is determined is 1/3 of 1/800 cmm or 1/2400 cmm, or $\frac{1}{2,400,000}$ cc.

## SUMMARY.

Tomato products promptly made from stock judged acceptable by visual inspection never show high counts of microorganisms. Similarly, products made from stock obviously not good or from stock improperly handled usually show high counts. It may therefore be assumed that high counts of organisms in such products indicate unmistakably that the stock used was in bad condition or was handled in an insanitary manner during manufacture.

It was found that tomato pulp stored in barrels usually gave high microscopical counts; hence it would seem inadvisable to use barrels for storing the product.

Field work performed during the past three seasons has proved that with proper equipment and factory management there is no reason for stock ready for the cyclone to contain over 1 per cent of decayed material.

In factories where the stock is properly handled the mold count is of greater importance than the counts on the other organisms in judging the condition of the raw stock. High counts of yeasts and spores, and bacteria are more frequently an indication of secondary than of primary spoilage. A low mold, yeast and spore, or bacterial count does not necessarily indicate sound stock, but a high count in any of these organisms always indicates bad stock or improper handling.

It was found that of the samples made in the laboratory none with less than 5.5 per cent of rot gave a mold count of more than 50. In the case of the factory samples the mold count rises sharply from 0 to 1/2 per cent of rot. Beyond 1/2 per cent the rate of rise gradually decreases, until after 20 per cent of rot the rate of increase is slow. A mold count of 40 may be obtained in samples having any amount of rot between 2.2 and 100 per cent.

A yeast and spore count of 20 represents about 1 per cent of decay. From this point the rate of increase is slow.

A bacterial count below 15,000,000 indicates little as to the amount of decay. Beyond this point, however, up to 20 per cent of rot the rate of increase is about 20,000,000 for each per cent of rot.

An investigation of the manufacture of tomato sauces and pastes in Italy showed that Italian products should be equal to American products made under similar conditions. The mold count for the concentrated products was found to be about the same as that for pulp, and the yeast and spore and bacterial counts to be proportional to the degree of concentration. Sauces and pastes made from objectionable material run particularly high in yeasts, spores, and bacteria. High counts on this class of products, then, indicate bad stock or insanitary handling.

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UNITED STATES DEPARTMENT OF AGRICULTURE
**BULLETIN No. 582**
OFFICE OF THE SECRETARY.
Contribution from the Office of Farm Management.
W. J. SPILLMAN, Chief.

Washington, D. C. January 7, 1918.

# FARM MANAGEMENT AND FARM PROFITS ON IRRIGATED LAND IN THE PROVO AREA, UTAH LAKE VALLEY.

By L. G. Connor, *Assistant Agriculturist.*

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The farm-management survey discussed in this bulletin was made in 1914 to check the results secured in a similar study[1] conducted in the same area during the previous year. The object of these surveys was to determine, approximately, the profits that farmers receive, or may reasonably expect to receive, in the irrigated areas of the intermountain region. (See Pls. I and II.) New data were collected with which to make a more complete analysis of the farm as a business enterprise in an effort to ascertain the factors which apparently control the income of the farmers in the above areas.[2]

## SOURCE OF DATA.

Farm-management survey records were secured from 106 farms. Two of these were discarded, as one operator secured nearly three-fourths of his total receipts from outside labor and the other virtually conducted a lodging house. The 104 records used in this bulletin are divided into the following classes: (1) Owners, (2) owners renting additional land, and (3) tenants. There are 75 records in the first, 22 in the second, and 7 in the third division. All the records were carefully checked a number of times, farms revisited one or more times when the records seemed inaccurate, and in some cases individual statements were sent back to farmers for them to recheck at their leisure, that the figures obtained might be more trustworthy.[1]

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[1] Bulletin 117, U. S. Dept. of Agriculture.

[2] Many thanks are due the farmers who were interviewed in the prosecution of this study. A considerable portion of them had to put themselves to some inconvenience in furnishing complete data on the results of their year's work. Acknowledgment is hereby tendered them for their hearty cooperation and active interest in the work. Thanks are also due the various persons engaged in marketing the farm products of this section (particularly to Mr. Wm. Roylance), officials of the Forest and Reclamation Services, and to members of the staff of the Utah Agricultural College (particularly to Dr. R. J. Evans and Prof. J. T. Caine, III) for information supplied during the course of the study.

## SUMMARY.

Following is a brief summary of the facts brought out by this study and of the conclusions drawn therefrom.

(1) The size of the farm business, the type of farming followed, and the diversity of income, each has an important bearing on profits. As regards size, the labor income from 26 small fruit farms and general farms averaged $350; for 29 large fruit and general farms, $598; and for 20 live-stock farms, $1,394. As regards type of farming, the labor income of 16 small fruit farms averaged $302; of 18 small general farms, $383; of 17 large fruit farms, $611; and of 24 large general farms, $646. Eighteen dairy farmers made an average labor income of $1,427, and three small poultry farms averaged $483.

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[1] In order that the reader may readily follow the discussion, certain technical terms which are used are explained. It is necessary that the reader understand them thoroughly; otherwise the interpretation of the results may be somewhat difficult. These terms are as follows:

*Farm capital.*—The farm capital is one-half of the combined value at the beginning and at the end of the year of the value of all real estate, improvements, machinery, live stock, feed and supplies, and cash necessary to carry on the farm business. It includes the value of the farmhouse, but not of the household furnishings.

*Receipts.*—The farm receipts include the amount received from the sale of all farm products and also the receipts from outside labor, rent of buildings, etc. If the value of buildings, stock, produce, or equipment is greater at the end of the year than at the beginning, the difference is considered a receipt.

*Expenses.*—The farm expenses represent the amount of money paid out during the year to carry on the farm business. If the value of buildings, stock, produce, or equipment at the end of the year is less than at the beginning, this decrease is considered an expense. Household or personal expenses are not included, except the cost to the farmer of board furnished to hired help. The value of labor performed by members of the farmer's family for which no payment was given is charged as an expense.

*Farm income.*—The farm income is the difference between the receipts and expenses. It represents the amount of money available for the farmer's living, providing he has no interest to pay on mortgages or other debts.

*Labor income.*—The labor income is the amount that the farm operator has left for his labor after 5 per cent interest on the average capital is deducted from the farm income. It represents what he earned as a result of his year's labor after the earning power of his capital has been deducted. In addition to the labor income the operator received a house to live in, fuel (when cut from the farm), garden products, milk, butter, eggs, etc. The labor income corresponds to what a hired man receives when he is given so much wages in cash, together with board and room, or, in the case of a married hand, so much wages in cash, together with a house to live in, and produce from the farm for his kitchen. Interest at 5 per cent is deducted in order that the results secured may be compared with the results of similar surveys made in other sections where the prevailing rate on farm mortgages is 5 per cent or thereabout. Although the prevailing rate of interest on farm mortgages is 8 per cent in Utah (6 per cent in the case of money borrowed from the State), the farmers who rent land in this section pay a little more than 4 per cent on the average.

(2) The greatest need of the small farmers in this district is more land to work. Failing this, outside labor is a necessity if a good living is to be secured.

(3) Although in many cases a greater diversification is needed, on the small general farms this is not nearly as important as an increase in size of farm.

(4) The small orchardist should increase the area of his farm if possible and should also diversify. When he diversifies the fruit grower should do so with a crop or crops the market for which is more certain than for fruit. Under existing conditions one of the best methods for doing the latter is by the growing of sugar beets. Beans would also appear to merit much attention in this area.

(5) In general, so far as practicable, the farmer taking more land should do so by rent or lease, rather than purchase subject to a mortgage, as he can usually secure the use of the land for little more than half what must be paid on a mortgage. The money saved can be used for subsequent purchase. This, of course, does not apply to the man with cash in hand for immediate purchase.

(6) Some operators live in town and travel many miles a day to and from the farms. From a farm-management viewpoint this is an inefficient system.

(7) With land values and labor cost so high, and the marketing situation so complicated, farmers in this area should make every effort to keep at the maximum that part of the family living which is secured directly from the farm. The garden should be one of the regular enterprises and should be given adequate care.

(8) A further increase in the number of very small farms in this region would seem to be unwise. The operators of such units have not enough land to keep them busy at profitable work. About 30 acres seems to be the smallest size for efficient management without much reliance on live stock. Forty to fifty, preferably about 50 acres, seems to be the smallest unit for efficient management where live-stock enterprises are given a prominent place by the typical farmer. This is especially true of dairying.

(9) When feasible, live-stock enterprises may well be made a part of the farm business. The kind and extent will depend on conditions. Men at present engaged in dairying should replace poor cows with better animals. Pork production merits more attention than it now receives.

(10) In general, owing to market conditions, the proper place for orchard and truck products in this region is on general farms where they are used as fillers in the business as a whole. Certainly fruit should be produced only on farms where the orchard enterprises are supplemented in a substantial way by more extensive activities. The general farms which grow truck and fruit as secondary enterprises approximate the ideal cropping combination for this region.

## PROFITS.

To facilitate this discussion the 75 records from farm owners were divided into three groups, as shown in Table 1.

The first group represents fruit and sugar-beet or truck farms, no one of which is as large as 27 acres, and most of them much smaller. The chief cash crops are fruit, beets, and truck, other crops being quite unimportant on these small units.

The second group comprises those farms of more than 27 acres in size, but on which practically the same crops are grown as on those in the first class. Productive live stock (usually stock other than work animals) is of but minor importance in either division. The men operating more than 27 acres derive a greater proportion of their crop receipts from grain, hay, and sugar beets than from fruit. Considerably more than half of the total receipts comes from the sale of crops in both of these groups.

The third group comprises the live-stock farms from which records were secured. Practically half of the total receipts on these farms comes from the sale of stock and animal products, while only a little more than a fourth of the total receipts comes from the sale of crops. The most important cash crop is the sugar beet, and fruit is a minor consideration if present. (See Table 7.)

TABLE 1.—*Average area, capital, receipts, expenses, farm income, and labor income on 75 farms operated by their owners. (Utah Lake Valley.)*

| Item. | First group (26 small farms). | Second group (29 fruit and beet farms). | Third group (20 live-stock farms). | All farms. |
|---|---|---|---|---|
| Size of farms......acres.. | 16.48 | 77.20 | 106.65 | 63.99 |
| Tillable area per farm......do.... | 15.04 | 56.64 | 68.06 | 45.26 |
| Crop area per farm......do.... | 13.34 | 46.05 | 47.81 | 35.18 |
| Capital...... | $6,142 | $13,337 | $16,507 | $11,688 |
| Receipts...... | 1,311 | 2,460 | 3,793 | 2,417 |
| Expenses...... | 654 | 1,195 | 1,574 | 1,105 |
| Farm income...... | 657 | 1,265 | 2,219 | 1,312 |
| Labor income...... | 350 | 598 | 1,394 | 728 |

From Table 1 it is seen that the average size of the 26 small farms is 16.48 acres, with 15.04 acres of tillable land and 13.34 acres in crops. The average labor income from the operation of these small farms is $350. In addition to this amount, the operator had the use of such products as the farm furnished toward the living of the family. If he had no mortgage on which interest had to be paid, the farmer had the total farm income ($657) for living expenses and savings against the inevitable "rainy day." The survey in 1913 showed that the farmers similar to those in group 1, Table 1, made a labor income of $247, or practically a sixth less than in 1914. In the latter year more than half of these men reported large receipts from outside labor, labor done off the farm when farm work is not pressing, and when the time of both man and team would otherwise be largely wasted. The item of outside labor will be discussed in some detail later. The average receipts therefrom considerably more than account for the difference between the labor incomes of the farmers on small units as shown by the 1913 and 1914 surveys. One man in group 1 made a labor income of more than $1,000, seven of more than $500, and one had a minus labor income, i. e., he failed to pay interest on his capital, and got nothing for his year of farm work.

The second group of farms, 29 in number, is of the same general type as the first, but the average area is more than four times as large and the crop area more than three times as large, 46.05 as against 13.34 acres. The capital is a little more than double that of group 1, and the labor income two-thirds greater. Seven of these farmers made labor incomes of more than $1,000, 14 of more than $500, and 4 made minus labor incomes. They simply illustrate the fact that it takes money to make money, but that the more there is the more may be lost.

The third group of farms, 20 in number, comprises the live-stock units operated by owners. Two of these men breed and raise horses, four specialize in chickens, and the remainder conduct dairy farms. These operators produce for the home market almost exclusively. This type of farming is not yet overdone, but the possibilities for extension, except along certain lines, seem somewhat limited. The average labor income is $1,394.

The average labor income of all 75 owners ($728) compares favorably with labor-income figures secured in surveys made in other parts of the country.

TABLE 2.—*Average area, capital, receipts, expenses, farm income, and labor income on 22 farms operated by owners renting additional land. (Utah Lake Valley.)*

| Item. | First group (8 small farms). | Second group (14 general farms). | All farms. |
|---|---|---|---|
| Size of farm ........ acres | 20.03 | 113.25 | 79.35 |
| Farm area owned ........ do | 8.03 | 89.18 | 59.67 |
| Additional area rented ........ do | 12.00 | 24.07 | 19.68 |
| Tillable area per farm ........ do | 18.59 | 47.62 | 37.07 |
| Crop area per farm ........ do | 17.00 | 43.70 | 33.99 |
| Capital | $3,597 | $8,041 | $6,425 |
| Receipts | 1,026 | 2,197 | 1,770 |
| Expenses | 448 | 1,095 | 859 |
| Farm income | 578 | 1,102 | 911 |
| Labor income | 398 | 700 | 590 |

Table 2 presents the results from 22 farms where the operator owns an area which he deems too small for profitable farm management and rents additional land to overcome this drawback. This method of operation is becoming more and more general here, as elsewhere, with the rise in land values. It represents a step midway between tenant and owner, and is very effective in enabling men with limited capital to increase their labor incomes with but a small increase in their investment. The first group in Table 2, with but three-fifths as much capital as the small owners in Table 1 ($3,597 as against $6,142), made considerably more labor income ($398 as against $350). They raised but little fruit, devoting a large part of their crop area to sugar beets. The size of farm and the crop area is a little larger than with the men in group 1, Table 1.

The second division in Table 2 comprises 14 farms comparable to those of the same group in Table 1. One of these farms is operated by a man who owns considerable range land, which he is just beginning to improve, and who rents a small irrigated area in addition to a few acres of such land already owned. The crop area of these two groups is a proper measure for comparison. The average capital of these men renting additional land is $8,041 and the labor income $700. With less than two-thirds as much capital, they make practically one-fifth more labor income than the larger owners operating fruit and general farms. Four of these "renting owners" devote considerable attention to live stock. If they are omitted, the other 10, with a size of business but a little more than one-third as large as the operators in group 2, Table 1, make a labor income of $581. This is practically as large as that of the men with whom they are compared.

The last group in Table 2 shows the results for all the farmers renting land in addition to the area owned. These men are compared with the last group in Table 1, which presents the average for all farms operated by their owners. The owners had considerably more tillable land, owing to the inclusion in Table 2 of a unit composed largely of unimproved land which was just beginning to be brought under cultivation. The average tillable and crop area in the two classes under discussion is a proper measure of size. On somewhat smaller farms, and with a little over half as much capital as the average owner, the man renting additional land made an average labor income of $590, or nearly six-sevenths as much as that of the straight owners ($728). The greater proportion of live-stock farms run by owners accentuates the difference in labor income in their favor.

The average labor income of all the owners and owners with additional land rented is $697. The average capital is $10,096. This compares favorably with returns from a similar size of business in other parts of the country.

TABLE 3.—*Average area, capital, receipts, expenses, farm income, and labor income on 18 dairy farms. (Utah Lake Valley.)*

| | Average. | | Average. |
|---|---|---|---|
| Size of farm ........ acres ... | 119.46 | Receipts .................... | $4,227 |
| Tillable area per farm .. do ... | 82.88 | Expenses .................... | 1,872 |
| Crop area per farm .... do ... | 57.46 | Farm income ................. | 2,355 |
| Capital ..................... | $18,562 | Labor income ................ | 1,427 |

Table 3 presents the average of all the dairy farms included in the survey. Not all are operated by owners, there being two tenant farms included and two which are operated by owners with additional land rented. These are all handled as though run by straight owners, the operators being charged with the landlord's expenses, credited with the corresponding receipts and interest on the landlord's investment deducted from the farm income to secure the labor income. Six of these farms sold butter or butter fat, 11 sold market milk, and 1 sold as much of one as of the other. The market-milk men averaged approximately $1.45 per 100 pounds for their product, while butter sold for 30 to 35 cents, and butter fat for 28 to 32 cents per pound. The men selling whole milk averaged somewhat larger labor incomes than the others, but their line of production is quite limited and the market for milk is already fully supplied except for a short time in late summer. One of the butter-fat farms, a large, well-managed unit, made a labor income better than most of these marketing the product as whole milk. The skim milk was fed to hogs, and the hogs were raised with a minimum of labor. The receipts from hogs largely account for the unusually high profitableness of this farm.

TABLE 4.—*Average area, capital, receipts, expenses, farm and labor income on seven tenant (rented) farms. (Utah Lake Valley.)*

| Item. | Farm. | Tenant. | Landlord. |
|---|---|---|---|
| | *Acres.* | | |
| Size of farm | 89.08 | | |
| Tillable area per farm | 79.11 | | |
| Crop area per farm | 58.23 | | |
| Capital | | $1,117 | $17,469 |
| Receipts | | 2,118 | 1,617 |
| Expenses | | 1,050 | 589 |
| Farm income | | 1,068 | 1,028 |
| Labor income | | 1,012 | |
| Per cent on investment | | | 5,793 |

Table 4 presents the results secured from 7 farms operated by tenants. The tenants made a labor income of $1,012, and the landlords 5.79 per cent on their investment.

### RENTING COMPARED WITH BUYING.

From the preceding tables and discussion it seems very clear that the man with limited capital should rent rather than buy land in this area. The prevailing rate of interest on farm mortgages is 8 per cent. The average owner of the 22 renting additional land had the use of $4,447 in real estate belonging to the landlords, and paid only 4.1 per cent for it ($182). The tenants paid less than 6 per cent on the average, but with only $1,100 owned capital they made labor incomes much larger than the men in Table 2 or in the first two groups in Table 1. The man with a small farm would do well to rent additional land and use the capital represented at a relatively low rate of interest until he can buy outright, rather than borrow money at 8 per cent in order to buy. The savings from the operation of larger farms could perhaps be loaned at 8 per cent to trustworthy neighbors desirous of buying at the time, and thus earn double the interest which would have been paid if put into the bank.

So far as the writer was able to discover, recent purchases of farm land in the Provo area, when made by farmers who had acquired the money by farm operations, usually have been effected by men operating units larger than those in the first groups of Tables 1 and 2; that is, the small owners and small owners with additional rented land. In other words, these purchases have been made by men operating larger farms.

While a large part of the farm income in this section is available for living expenses and savings, practically all so available to the small operators is used for living expenses, and very little reaches the savings account in the bank. This is another argument in favor of the men with limited capital renting land rather than buying in this area at the present time. It enables them to farm a larger area.

## DISTRIBUTION OF RECEIPTS.

Tables 5 and 6 present the distribution of farm receipts under the different headings. Practically six-tenths of the total receipts in the first two groups in Table 5 and the first in Table 6 come from crops. The second division of Table 6 agrees with the others if the four live-stock farms included in it are omitted. If the increase in inventory owing to new machinery bought and improvements made is excluded from the receipts and expenses, the proportion of receipts from crops in these groups is practically two-thirds of the total. In these divisions receipts from stock and stock products average low except in the second division of Table 6, which contains four live-stock farms. Without them this group does not vary from the others mentioned above. One-half of the percentage under "Increase of inventory" in groups one and two, Table 5, and group two, Table 6, are due to improvements and new machinery. Nothing under this head enters into the figure for the first division of the second table. The bulk of the miscellaneous receipts of the small operators and of the large owners (fruit and general farms) comes from outside labor.

The live-stock farms in Table 5 secure one-fourth of their receipts from crop sales, one-half from sales of stock and stock products, and virtually one-fourth from increase of inventory. One third of the last is due to new machinery and improvements.

The fourth group in Table 6 presents the distribution of the receipts for all 97 farms operated by owners and owners with additional land rented. Nearly a half comes from the sale of crops, almost a fourth from stock and stock products, 5 per cent from miscellaneous (largely outside labor), and nearly a fourth from increase of inventory, about two-fifths of which are due to new machinery and improvements. Excluding the last item, the receipts on all 97 farms average $2,049 per farm, of which 51.2 per cent comes from crops, 5.1 per cent from stock, 21.7 per cent from stock products, 5.8 per cent from miscellaneous, and 16.2 per cent from inventory increase due solely to farm activities.

TABLE 5.—*Distribution of farm receipts on 75 farms operated by their owners. (Utah Lake Valley.)*

| Source of receipts. | First group (26 small farms). | Proportion of total. | Second group (29 large fruit and beet farms). | Proportion of total. | Third group (20 live-stock farms). | Proportion of total. | Average (75 farms). | Proportion of total. |
|---|---|---|---|---|---|---|---|---|
| | | *Per ct.* | | *Per ct.* | | *Per ct.* | | *Per ct.* |
| Crops | $763 | 58.2 | $1,481 | 60.2 | $945 | 24.9 | $1,089 | 44.6 |
| Stock | 51 | 4.0 | 103 | 4.2 | 198 | 5.2 | 110 | 4.9 |
| Stock products | 54 | 4.0 | 87 | 3.5 | 1,710 | 45.0 | 509 | 21.0 |
| Miscellaneous (includes outside labor) | 147 | 11.2 | 140 | 5.7 | 51 | 1.4 | 117 | 4.8 |
| Increase of inventory (less decrease) | 296 | 22.6 | 649 | 26.4 | 889 | 23.5 | 592 | 24.7 |
| Total | 1,311 | 100.0 | 2,460 | 100.0 | 3,793 | 100.0 | 2,417 | 100.0 |

TABLE 6.—*Distribution of farm receipts on 22 farms operated by owners with additional land rented. (Utah Lake Valley.)*

| Source of receipts. | First group (8 small farms). | Proportion of total. | Second group (14 large general farms). | Proportion of total. | Average (22 farms). | Proportion of total. | Average for 75 owners and 22 owners with additional rented land. | Proportion of total. |
|---|---|---|---|---|---|---|---|---|
| | | *Per ct.* | | *Per ct.* | | *Per ct.* | | *Per ct.* |
| Crops | $653 | 63.7 | $1,049 | 47.8 | $905 | 51.2 | $1,049 | 46.2 |
| Stock | 26 | 2.5 | 124 | 5.6 | 88 | 5.0 | 105 | 4.6 |
| Stock products | 32 | 3.1 | 336 | 15.3 | 225 | 12.7 | 444 | 19.6 |
| Miscellaneous (includes outside labor) | 144 | 14.0 | 106 | 4.8 | 120 | 6.8 | 119 | 5.2 |
| Increase of inventory (less decrease) | 171 | 16.7 | 582 | 26.5 | 432 | 24.3 | 554 | 24.4 |
| Total | 1,026 | 100.0 | 2,197 | 100.0 | 1,770 | 100.0 | 2,271 | 100.0 |

Table 7 presents the distribution of crop receipts on the various farm types. It is evident that fruit is an important crop. The receipts for fruit per farm are $387, or 36.9 per cent of the crop receipts. The small owners go in relatively more heavily for fruit than any of the others. Fruit is nearly as important in the second group of this table as in the first, but in the third group it becomes quite secondary to other enterprises. Operators have been much discouraged in recent years over the outlook for fruit growing, especially peaches. The men not already on fruit farms do not feel that they can safely depend on such sources for their income. Accordingly the area of new plantings is small.

TABLE 7.—*Distribution of crop receipts on farms operated by their owners and on farms whose owners rent additional land.*

| Source of crop receipts. | On 75 farms operated by their owners. | | | | | | | | On 22 farms operated by owners renting additional land. | | | | | | Average (97 farms). | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First group (26 small farms). | | Second group (29 fruit and beet farms). | | Third group (20 live-stock farms). | | Average (75 farms). | | First group (8 small farms). | | Second group (14 general farms). | | Average (22 farms). | | | |
| | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. |
| | | *Per ct.* | | *Per ct.* | | *Per ct.* | | *Per ct.* | | *Per ct.* | | *Per ct.* | | *Per ct.* | | *Per ct.* |
| Corn | .... | .... | .... | .... | $4 | 0.4 | $1 | 0.1 | .... | .... | .... | .... | .... | .... | $1 | 0.1 |
| Potatoes | $57 | 7.5 | $41 | 2.8 | 43 | 4.6 | 47 | 4.3 | $87 | 13.3 | $83 | 8.0 | $85 | 9.4 | 56 | 5.3 |
| Wheat | 8 | 1.1 | 78 | 5.3 | 6 | .6 | 34 | 3.1 | 39 | 6.0 | 49 | 4.6 | 45 | 5.0 | 37 | 3.5 |
| Oats | .... | .... | 5 | .3 | 1 | .1 | 2 | .... | .... | .... | 22 | 2.0 | 13 | 1.4 | 5 | .5 |
| Hay | 5 | .6 | 100 | 6.7 | 20 | 2.1 | 46 | 4.2 | 4 | .6 | 45 | 4.3 | 30 | 3.3 | 42 | 4.0 |
| Beets | 162 | 21.2 | 399 | 26.9 | 783 | 82.9 | 419 | 38.4 | 473 | 72.4 | 629 | 60.0 | 572 | 63.5 | 455 | 43.4 |
| Truck crops | 65 | 8.5 | 61 | 4.1 | 13 | 1.4 | 50 | 4.6 | 22 | 3.4 | 88 | 8.3 | 64 | 7.0 | 53 | 5.1 |
| Apples | 162 | 21.2 | 166 | 11.2 | 59 | 6.2 | 135 | 12.4 | 21 | 3.2 | 52 | 5.0 | 40 | 4.4 | 114 | 10.9 |
| Peaches | 175 | 23.0 | 230 | 15.6 | 5 | .5 | 151 | 13.9 | .... | .... | 56 | 5.3 | 35 | 3.9 | 125 | 11.9 |
| Other fruit | 122 | 16.0 | 367 | 24.8 | 8 | .9 | 187 | 17.2 | 7 | 1.1 | 25 | 2.5 | 19 | 2.1 | 148 | 14.1 |
| Miscellaneous crops | 7 | .9 | 34 | 2.3 | 3 | .3 | 17 | 1.6 | .... | .... | .... | .... | .... | .... | 13 | 1.2 |
| Total | 763 | 100 | 1,481 | 100 | 945 | 100 | 1,089 | 100 | 653 | 100 | 1,049 | 100 | 905 | 100 | 1,049 | 100 |

A person driving through this section in a casual way might come to the conclusion that fruit formed the chief product. In 1914, however, fruit contributed but one-sixth of the total farm receipts on the 97 farms of Table 7. Excluding dry-land farms the average size of 100 farms surveyed is 54.64 acres, with 5.22 acres in bearing fruit and 1.76 acres not yet in bearing. Fruit, bearing and not bearing, occupied only one-eighth of the farm area. On the whole, it seems just as well that the proportion is no larger.

The sugar beet is the most important cash crop for this area as a whole. (See Pl. III.) Nearly 50 per cent of the total crop sales on the 97 farms in Table 8 and a fifth of the total receipts were from beets. Those operators who rent additional land secure from three-fifths to three-fourths of their crop receipts from beets, and the live-stock farmers average more than four-fifths of their crop receipts from this source.

Sugar beets in Utah bring only a moderate price—$4.75 to $5 per ton—in most cases in the Provo area. But this price is steady. The growers know what their beet crops will bring per unit; the uncertainty attending the marketing of the fruit crop is absent. With land values as high as is the case in this district and with the distance to outside markets so great, crops yielding a fairly high return per acre and capable of being marketed at home must command a large degree of attention. The predominance of the sugar-beet crop is therefore only to be expected. It is the mainstay of Utah farming in the irrigated areas. If for any reason this crop were to become permanently unprofitable, farm-management problems of the gravest kind would arise.

Table 8 presents data for a number of small farmers who specialize in sugar beets and grow little or no fruit. The importance of the sugar-beet crop in the Provo area is again made clear.

TABLE 8.—*Distribution of receipts from 16 sugar-beet farms. (Utah Lake Valley.)*

| Item. | First group (8 farms operated by owners). | Second group (8 farms operated by owners renting additional land). | Item. | First group (8 farms operated by owners). | Second group (8 farms operated by owners renting additional land). |
|---|---|---|---|---|---|
| Size of farm..............acres.. | 16.33 | 20.03 | Capital.......................... | $7,039 | $3,597 |
| Farm area owned........do.... | 16.33 | 8.03 | Receipts......................... | 1,140 | 1,026 |
| Additional area rented..do.... | | 12.00 | Expenses......................... | 414 | 448 |
| Crop area...............do.... | 13.50 | 17.00 | Farm income...................... | 726 | 578 |
| Area in sugar beets......do.... | 6.03 | 6.60 | Receipts from outside labor... | 166 | 135 |
| Receipts from sugar beets, dollars........................ | 503.00 | 473.00 | Labor income..................... | 374 | 398 |
| Proportion of total receipts from crops........per cent.. | 73.00 | 72.00 | | | |

The first group comprises the eight small farms of owners who specialized in this crop. Nearly half the crop area is in beets, which are raised on 6.03 acres. The labor income averages $374, of which $166 came from outside labor. The second group comprises the eight small owners with additional land rented. They have a larger area in crops and slightly more land in beets. Their labor income averages $398, of which $135 comes from outside labor. In both groups sugar beets brought in nearly half the total receipts and practically three-fourths of the crop receipts. The larger area cropped by the men in group 2 suggests that they have a slightly greater diversity of farm enterprises, which normally would tend to give a better labor income. It should be noted that the small owners with additional land rented have just half as much capital invested as the small owners, yet they manage more land and make better labor incomes than do the latter, and derive a larger percentage of their incomes from strictly farm operations.

## DISTRIBUTION OF EXPENSES.

Table 9 presents the distribution of expenses under the various headings. Improvements and new machinery are a surprisingly large item. This was due in large measure to the erection of new dwellings or other buildings by some operators in four of the groups, to a considerable extent with borrowed money. The expense for labor is thus decreased to a little over one-third of the total expenses.

TABLE 9.—*Distribution of farm expenses on 97 farms (Utah Lake Valley).*

| Item of expense. | On 75 farms operated by their owners. | | | | | | | | On 22 farms operated by owners renting additional land. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First group (26 small farms). | | Second group (29 fruit and beet farms). | | Third group (20 live-stock farms). | | Average (75 farms). | | First group (8 small farms). | | Second group (14 general farms). | | Average (22 farms). | |
| | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. | Per farm. | Proportion of total. |
| | | *Per cent.* | | *Per cent.* | | *Per cent.* | | *Per cent.* | | *Per cent.* | | *Per cent.* | | *Per cent.* |
| Paid labor and board | $130 | 20.2 | $244 | 20.4 | $397 | 25.2 | $245 | 22.3 | $68 | 15.1 | $206 | 18.8 | $156 | 18.2 |
| Family labor | 61 | 9.5 | 192 | 15.2 | 218 | 13.9 | 154 | 14.0 | 38 | 8.5 | 110 | 10.0 | 84 | 9.8 |
| Improvements and new equipment | 143 | 22.2 | 283 | 24.6 | 267 | 17.0 | 231 | 21.0 | ..... | ..... | 218 | 19.9 | 138 | 16.1 |
| Repairs | 23 | 3.6 | 51 | 4.3 | 59 | 3.7 | 43 | 3.9 | 38 | 8.5 | 38 | 3.5 | 38 | 4.4 |
| Feed | 74 | 11.5 | 79 | 6.6 | 221 | 14.1 | 116 | 10.5 | 44 | 9.8 | 85 | 7.8 | 70 | 8.1 |
| Horseshoeing | 10 | 1.5 | 14 | 1.2 | 19 | 1.2 | 14 | 1.2 | 6 | 1.3 | 13 | 1.2 | 10 | 1.2 |
| Seed and fertilizers | 14 | 2.2 | 19 | 1.6 | 8 | .5 | 15 | 1.3 | 5 | 1.1 | 12 | 1.1 | 10 | 1.2 |
| Spray material | 14 | 2.2 | 25 | 2.1 | 5 | .3 | 16 | 1.4 | 2 | .4 | 10 | .9 | 7 | .8 |
| Machine work hired | 20 | 3.1 | 30 | 2.5 | 43 | 2.7 | 30 | 2.7 | 31 | 6.9 | 32 | 2.9 | 32 | 3.7 |
| Interest, taxes, etc | 70 | 10.9 | 144 | 12.0 | 175 | 11.1 | 127 | 11.4 | 157 | 35.2 | 250 | 22.8 | 216 | 25.1 |
| Miscellaneous [1] | 41 | 6.4 | 80 | 6.7 | 65 | 4.1 | 60 | 5.4 | 16 | 3.6 | 52 | 4.8 | 38 | 4.4 |
| Stock purchased | 43 | 6.7 | 34 | 2.8 | 97 | 6.2 | 54 | 4.9 | 43 | 9.6 | 69 | 6.3 | 60 | 7.0 |
| Total | 643 | 100 | 1,195 | 100 | 1,574 | 100 | 1,105 | 100 | 448 | 100 | 1,095 | 100 | 859 | 100 |

[1] Includes decrease inventory.

Many operators pay members of the family for labor performed in rush periods at the same rate as is paid hired labor. The members of the family then buy their own clothes. Many men paid a substantial wage to grown or nearly grown sons for all work done on the farm. In these cases the labor was classed as hired labor.

The item for machine work hired relates principally to the seeding of the sugar-beet crop. The factory furnishes seed, machine, and labor, and charges $2.75 per acre. No attempt was made to segregate the actual cost of the seed, as the work is a contract job at a flat rate. The part of this item not covered by the beet seeding deals largely with grain-binder and drill hire and that of orchard sprayers. The areas in grain are usually very small, and the operators fully realize that it does not pay them to keep a drill or binder for such small acreages unless they can hire them out to their neighbors. Much of the small grain is broadcasted by hand. The item under "Interest, taxes, etc.," is disproportionately high in the case of owners with additional land rented, because it includes cash rent.

## THE FARM FAMILY—MORTGAGES.

In Table 10 are presented data on the age of the farmer, the size of the farm family, and the amount of the mortgage on the farm.

TABLE 10.—*Age of the farmer, amount of mortgage, and size of family on farms operated by their owners and on farms whose owners rent additional land. (Utah Lake Valley.)*

| Farm group. | On 75 farms operated by owners. | | | | On 22 farms operated by owners renting additional land. | | | |
|---|---|---|---|---|---|---|---|---|
| | Number of farms. | Age of operator. *Years.* | Amount mortgage. | Number in family on farm. | Number of farms. | Age of operator. *Years.* | Amount mortgage. | Number in family on farm. |
| Small farms | 26 | 46.3 | $304 | 5.1 | 8 | 40.6 | $162 | 4.8 |
| General and fruit farms | 28 | 50.1 | 800 | 7.0 | 14 | 43.6 | 721 | 5.0 |
| Live-stock farms | 21 | 51.0 | 729 | 5.8 | ........ | ........ | ........ | ........ |
| Total and average | 75 | 49.0 | 608 | 6.0 | 22 | 42.5 | 518 | 4.9 |

A very encouraging fact is the small size of the average mortgage on the farms reported in this survey. The amount of borrowed capital ranges (by groups) from 4.2 to 9 per cent of the total capital invested by the operators. The average for all 97 owners and owners with additional land rented is but 5.7 per cent of their total investment. This means that the average farmer of those visited in this particular survey has nearly the whole of his farm income for living expenses and savings.

With increased size of farm by groups (see Table 10) the age of the farmer increases. This appears to be the rule wherever farm-management surveys have been made. The average age of the owners is 49 years, while the average age of the owners with additional land rented is 42.5. A considerable difference in these ages is but natural. The owners with additional land rented are in a period of transition from tenancy to ownership. The seven tenant farmers in Table 4 average 33.7 years in age, as would be expected in a group representing a still earlier period in the transition from tenant to owner.

The size of the farm family averages large, just as in 1913. The tenant farmers average 4.4 persons per farm family as against 4.9 for owners with additional land rented, and 6 for the owners. The differences are largely due to difference in age of the farmers in these groups. In this connection it should be noted that the "farm family" contains only those members of the operator's family living at home. Members living elsewhere are not included.

The average value of the farm dwelling is $1,074, other houses $96, and other buildings $430. The buildings other than the dwellings are of low value on all but the dairy farms. In most cases, the dairy farmers have learned the greater efficiency of feed when the cow barns are fairly comfortable in the cold season.

## WORK HORSES.

The data concerning the number of work horses per farm and the crop acres per horse are presented in Table II.

TABLE 11.—*Number of work horses and crop area per horse (Utah Lake Valley).*

| Farm group. | Number of farms. | Number of work horses. | Crop area per horse. |
|---|---|---|---|
| | | | *Acres.* |
| Small farms | 34 | 1.94 | 7.32 |
| General and fruit farms | 49 | 3.71 | 12.14 |
| Live-stock farms | 21 | 4.60 | 11.30 |
| Total or average | 104 | 3.31 | 10.98 |

The small farms have 1.94 work horses and only 7.32 acres of crops per horse. This shows a relatively low efficiency of the farm draft. The larger farms have an average of 11.89 acres of crops per horse, showing 62 per cent greater capacity in this respect. The average for all farms over 60 acres in size shows 70 crop acres and 4.76 work horses, or 14.7 crop acres per horse. The efficiency of the farm draft is double that in the case of the small farms. With the total cost of keeping a horse a year ranging from $70 to $100, the inefficient use of the farm draft on small farms represents an appreciable reduction of the labor income unless the horses can be used in idle periods at outside work.

With the cost of keeping a horse so high, an average charge of from nearly $10 to approximately $14 per acre would have to be made for horse labor per crop acre on the small farms, and just half as much on the farms over 60 acres in size. The average crop acres per horse for all farms was 10.98. The average charge per crop acre for horse labor would therefore range between approximately $6.40 and $9.

## THE FARMER'S LABOR.

An estimate was obtained from each farmer on the value of the work done by him for that year. The average of all these estimates was $429, which is considerably higher than the average labor income earned by the small owner, or small owner with additional land rented. In other words, the operators in these two groups received less for their labor than they would have done had they worked out by the year for $429, plus a house to live in, and products of the farm furnished by the employer for use in the kitchen. Their total yearly earnings would also have been greater if they had sold their farms, put out the money at 5 per cent interest, and hired out in this way.

The actual wages paid to dependable men by the year were frequently higher than the estimates of the farmers as to the value of their own year's work. These wages usually range from $420 to $480 per year.

## INFLUENCE OF OUTSIDE LABOR ON LABOR INCOME.

In commenting on group one, Table 1, the fact was mentioned that outside labor was very important in increasing the labor income of the small operators in 1914. Table 12 is presented to show just how important this item really is.

TABLE 12.—*Importance of outside labor in increasing income on small farms. (Utah Lake Valley.)*

| Item. | First group (15 small farms with 20 per cent or more of receipts coming from outside labor). | Second group (26 small farms [owners] showing amount of receipts from outside labor). | Third group (8 small farms [owners], with additional land rented, showing receipts from outside labor). | Fourth group (29 large fruit and beet farms [owners] showing receipts from outside labor). |
|---|---|---|---|---|
| Size of farm.....acres.. | 18.06 | 16.48 | 20.03 | 77.20 |
| Crop area per farm.....do.... | 14.25 | 13.34 | 17.00 | 46.05 |
| Capital | $5,362 | $6,142 | $3,597 | $13,337 |
| Receipts | $1,176 | $1,311 | $1,026 | $2,460 |
| Labor income | $430 | $350 | $398 | $598 |
| Receipts from outside labor | $301 | $141 | $135 | $96 |
| Percentage of labor income from outside labor | 70 | 39 | 34 | 16 |

The total receipts here shown do not include receipts from increased inventory owing to new machinery bought or improvements made. The cash outlay for these items is credited as a receipt, and it is also debited as an expense. These items thus cancel each other. Many men made no improvements and bought no machinery in 1914. The farm receipts on all farms appearing in Table 12, therefore, are made perfectly comparable, both individually and by groups, by omitting the items in question from the receipts. This omission gives a figure which represents the receipts from the operation of the farm merely as a farm business, and not as affected by real estate operations or machinery increase. The labor income is in no way affected.

The first group in Table 12 comprises those operators whose receipts from outside labor amounted to 20 per cent or more of their total receipts. There are 15 such operators, 10 small owners, and 5 small owners with additional land rented. The average farm in this class contained 18.06 acres of land, with 14.25 acres in crops. The capital invested was $5,362. The operator received $301 for outside labor, or 70 per cent of his labor income ($430). The men in this group had farms too small to keep themselves and their families busy. Accordingly, they sought outside employment in their spare time. Frequently an operator would send a son with the team to work on railroad construction. When this was done, the operator's team was credited with only half the wages received in most cases, as a well-grown son could command the other half. In each case as fair a division as possible was made of these receipts, and care was taken not to give undue credit for such items to the operator. One man worked at boiler making in the winter, another as a mill hand. One runs a thrashing machine, one is a school supervisor, and another is a landscape painter. Two men earned considerable money with their orchard sprayers. The remainder, and some of the above, did considerable hauling with their teams.

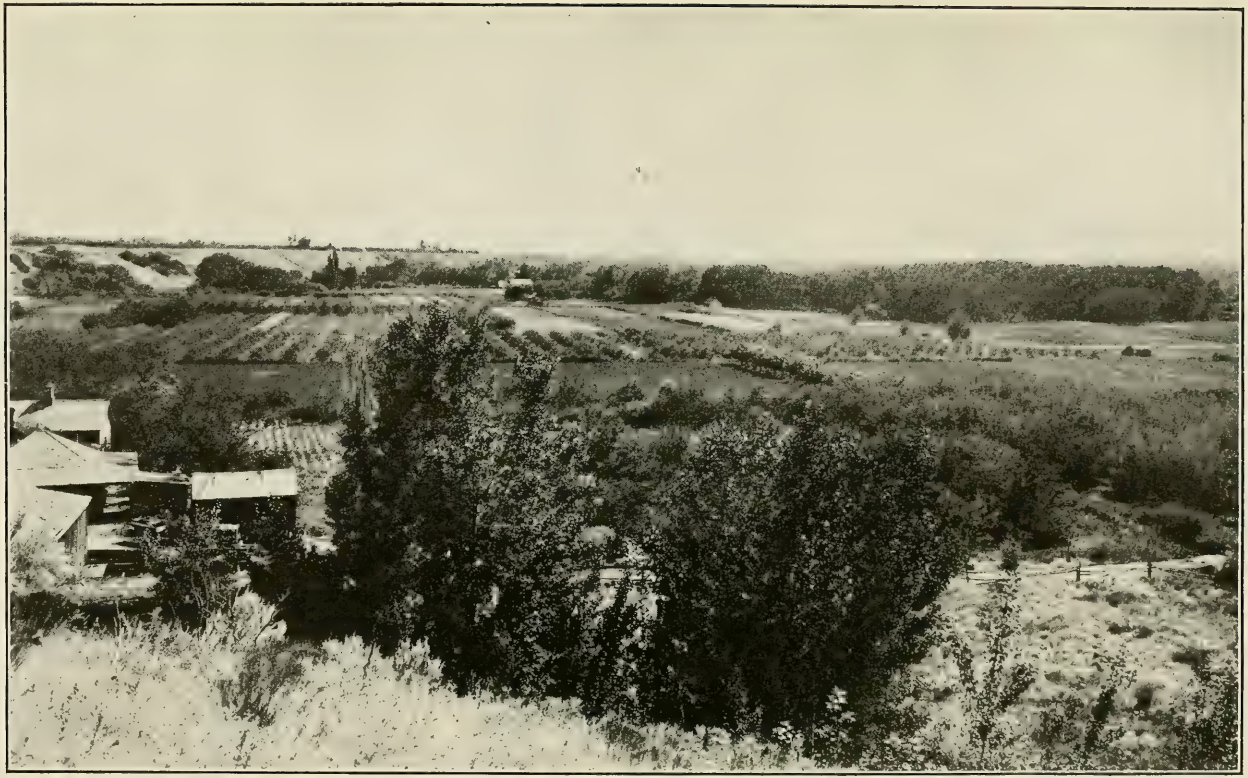
Group 2 in Table 12 presents the results for all the small owners. (See group 1, Table 1.) These men averaged $141 in receipts from outside labor, or more than one-third of their labor income. Group 3 shows similar results for the eight small farms operated by owners with additional land rented. (See group 1, Table 2.)

In the fourth division, Table 12, outside labor, while still important, figures much less prominently in the farm receipts, as less than a sixth of the labor income is derived from that source. These men did not make much more than the normal amount from such work. The average labor income for all the farms in groups 2, 3, and 4, 62 in number, amounts to $475. Twenty-five per cent of this labor income, or $120, comes from outside labor. The larger owners with additional land rented (see group 2, Table 2), the live-stock farmers (see group 3, Table 1), and the tenant farmers (see Table 4), had little or no time to engage in outside work. The labor on the farm kept these men busy, and their receipts from outside labor are practically negligible.

Table 12 simply shows how inadequate the small farm usually is to furnish sufficient labor for the operator and his family. The size of business on these small Utah farms is comparable with farms very much larger in area in nonirrigated sections, and the intensive type of farming followed on irrigated land calls for a labor supply commensurate with the size of business, but the operator and his family are often confronted with slack periods of considerable duration during the crop-growing season. The farms often are not large enough to permit a widespread adoption of enterprises which would call for labor in the idle periods. The small farmers in the Provo area took advantage of these periods of farm inactivity to earn large additions to their farm receipts in 1914. An interurban trolley

THE WASATCH MOUNTAINS NEAR PROVO.

A large part of the bench land, such as that in the foreground, is in fruit. Much of the fruit land was a short-grass and sagebrush desert 15 years ago.



IRRIGATED LAND IN THE PROVO RIVER BOTTOMS BETWEEN EAST BENCH AND PROVO BENCH.

The semiarid vegetation in the immediate foreground and on the bottom land in the right foreground shows the effect of absence of water. The land cultivated by the first settlers was in these bottoms.

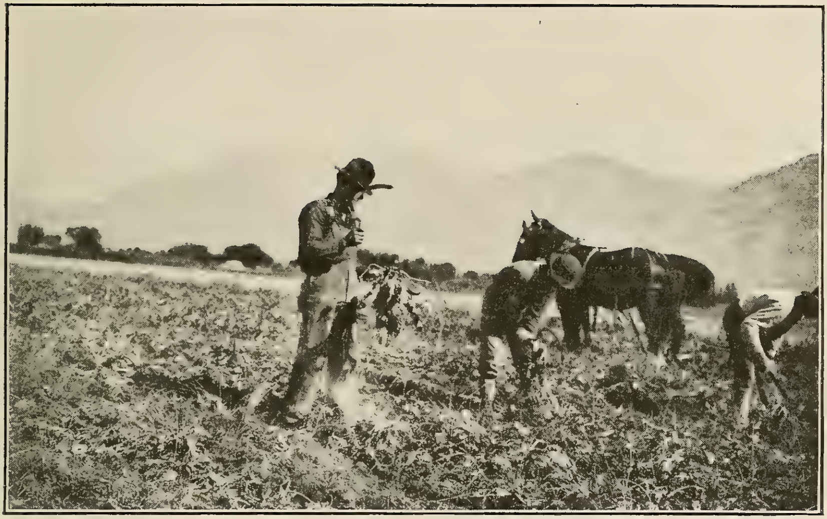


FIG. 1.—LIFTING AND "TOPPING" SUGAR BEETS.

In this area the best crop is grown almost entirely on the rich bottom land near the lake, while the "bench" land at the foot of the mountains is devoted largely to fruit.

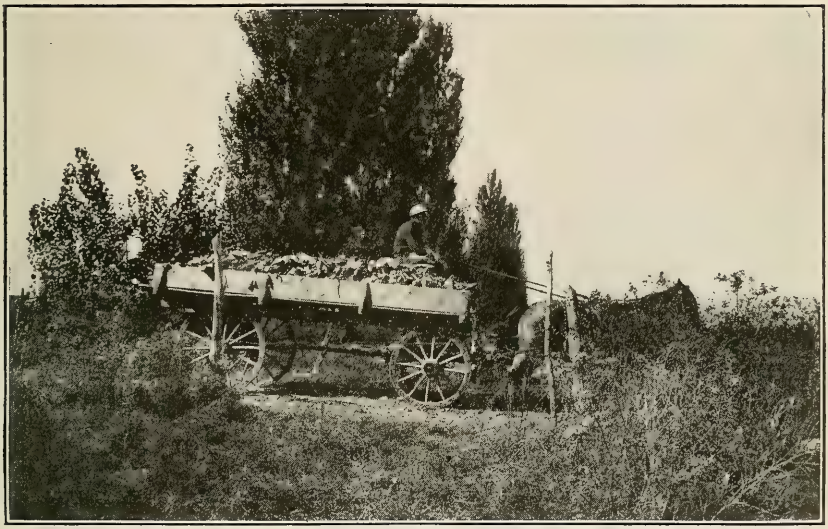


FIG. 2.—HAULING SUGAR BEETS TO THE SLICER.

Most operators use a two-horse or three-horse team on the beet rack.

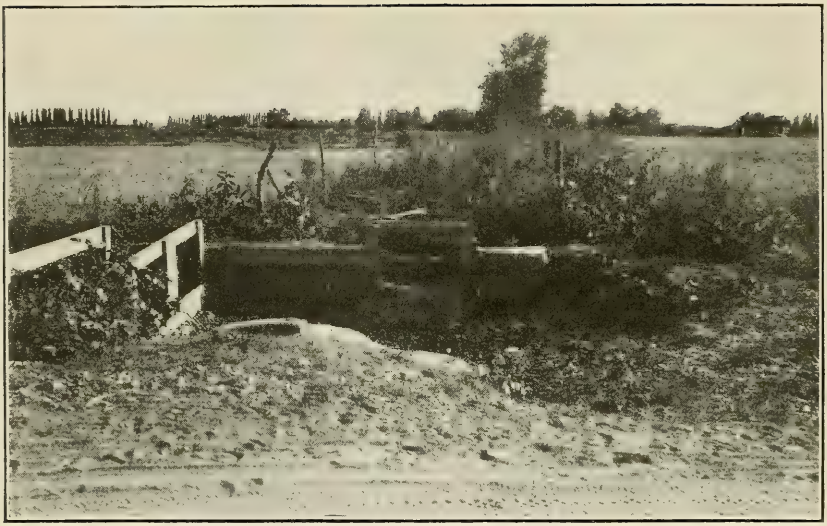


FIG. 1.—A BROAD, SHALLOW, WEED-COVERED IRRIGATION DITCH—THE USUAL CONDITION.

It is exceedingly difficult to keep the land clean when every irrigation after midsummer deposits fresh weed seed.

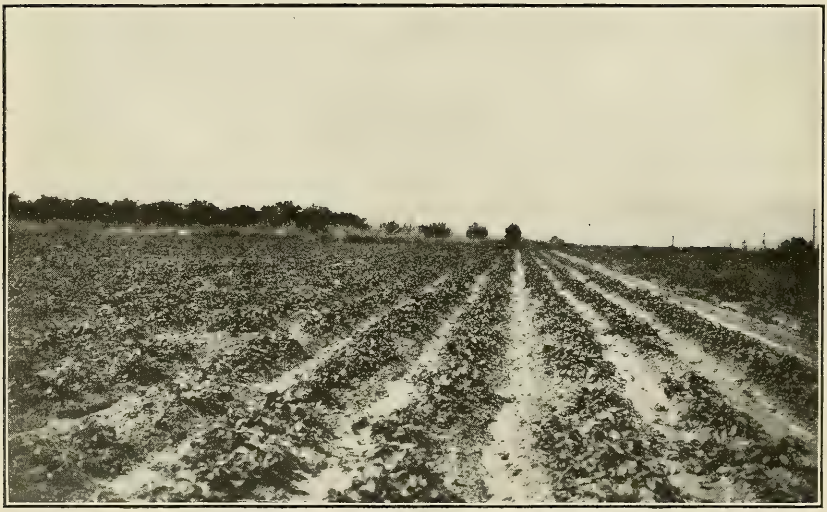


FIG. 2.—A STRAWBERRY FIELD ON PROVO BENCH.

Bare spots in the rows indicate the presence of insect pests.

line which was built into Provo created a much greater demand for man and team labor than ordinarily exists in this section. The farmers in question took full advantage of this unusual condition. The receipts from outside labor thus averaged much higher than they would in a normal year; and these receipts, as already noted, increased the labor incomes by more than 50 per cent in the case of the small owners and small owners with additional land rented. This increase is certainly a compliment to the energy of these operators. It must be borne in mind, however, in dealing with the labor incomes of these men that the figures for 1914 are above normal and that the conditions which made this possible are not apt to recur. The average labor incomes as shown in the 1913 survey[1] ($247 for the small owners and $231 for the small owners with additional rented) probably are nearer the returns ordinarily secured on such farms.

## RESULTS BY TYPE OF FARMING AS WELL AS BY SIZE.

In the preceding discussion the various details and the returns for work done have been presented by size of farm. In Table 13 are presented the vital details by size and by type of farming followed. This table is a digest of those which have preceded, with some additional data, and assembles the facts for all the farms for more convenient study.

In Table 13 the total acreage of crops grown does not quite check up with the crop acreage in line three, because the intervals in the young orchards are often planted in various crops, and hay is sometimes grown in the bearing orchards. All the farms are tabulated which can be used in the six classifications of (1) small fruit, (2) small general, (3) large fruit, (4) large general, (5) dairy, and (6) poultry farms.

In arriving at the amount of labor used the value of extra labor hired is all reduced to a man-time basis at $2 per day, the regular day wage. Such labor items include peach pickers (men), peach packers and berry pickers (girls), and the other miscellaneous labor used. Thus 10 peach packers averaging $1.20 per day each are equivalent to 6 men. Four boys earning 75 cents each per day at beet thinning are equivalent to 1.5 men. When members of the farm family work on other than a piece-work basis the value of their labor (above their board) is reduced to man time at the prevailing rate of wages for hands hired by the month. The amount of labor done by members of the family is practically the same in the first, second, and last groups, and in the three intermediate groups of the table. Although it is important at certain seasons, the actual amount of labor exchanged between neighbors is small, and it is mutually corrective between groups.

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[1] Bulletin 117, U. S. Dept. of Agriculture.

A minor, but a striking, factor bearing upon the labor used on all farms is the prevalence of abundant weed growths along the ditch banks. The fields are thus kept constantly seeded with weeds and are with difficulty kept clean. (See fig. 1, Pl. IV.)

TABLE 13.—*Labor used on different types of farm and the returns for labor.*

| | Small fruit farms. | Small general farms. | Large fruit farms. | Large general farms. | Live-stock farms. | |
|---|---|---|---|---|---|---|
| | | | | | Dairy. | Poultry. |
| Number of farms | 16 | 18 | 17 | 24 | 18 | 4 |
| Average per farm: | | | | | | |
| Acreage | 17.47 | 17.18 | 51.2 | 62.08 | 119.50 | 8.87 |
| Crop acreage | 14.29 | 14.12 | 41.08 | 45.65 | 57.46 | 8.00 |
| Capital | $6,248 | $6,400 | $13,915 | $13,125 | $18,562 | $6,046 |
| Crop sales | $804 | $700 | $1,630 | $2,311 | $1,088 | $278 |
| Stock sales | $62 | $30 | $206 | $103 | $235 | $160 |
| Stock product sales | $47 | $50 | $108 | $146 | [1] $1,745 | $859 |
| Miscellaneous receipts | $155 | $140 | $159 | $105 | $50 | ........ |
| Labor income | $302 | $383 | $611 | $646 | $1,427 | [3] $483 |
| Months of man labor used | 17.24 | 14.46 | 24.57 | 20.29 | 30.75 | 15.15 |
| Animal units | 4.33 | 4.31 | 9.25 | 8.81 | [2] 31.60 | 10.60 |
| Grain { acres | 1.80 | 3.33 | 4.78 | 15.25 | 12.11 | 2.50 |
| Grain { bushels | 68 | 140 | 196 | 467.50 | 527 | 110 |
| Hay and fodder { acres | 3.10 | 2.70 | 17.79 | 11.67 | 30 | 1.25 |
| Hay and fodder { tons | 9.66 | 8.50 | 52.40 | 37.42 | 102 | 5.25 |
| Beets { acres | .38 | 5.42 | .76 | 11.96 | 10.37 | 2.10 |
| Beets { tons | 6.00 | 86.20 | 10.60 | 182.92 | 194.25 | 41.30 |
| Fruit { acres | 6.51 | 1.70 | 14.55 | 3.80 | 2 | 1 |
| Fruit { bushels | 1,542 | 180 | 2,865 | 512.38 | 231.5 | 184.5 |
| Nonbearing fruit ... acres | 1.94 | .17 | 5.00 | 1.85 | .35 | .4 |
| Other crops ... do | 1.56 | 1.58 | 1.77 | 2.98 | 3 | .6 |
| Crop area in intensive crops ... per cent | 72.7 | 62.8 | 53.8 | 45.1 | 27.5 | 51.2 |
| Crop area per man ... acres | 10.0 | 11.7 | 20.1 | 27.0 | 22.3 | 6.34 |
| Months of labor per crop acre | 1.206 | 1.024 | .598 | .444 | .537 | 1.894 |
| Labor income per month of labor | $17.52 | $26.48 | $24 | $31.83 | $46.41 | $32.54 |
| Number of work horses per farm | 1.9 | 1.97 | 3.7 | 3.4 | 5.2 | 1.5 |
| Crop area per work horse ... acres | 7.52 | 7.17 | 11.10 | 13.43 | 11.01 | 5.33 |

[1] Receipts from dairy products.
[2] 17 milch cows.
[3] Omitting labor income of 1 exceptional farm, figure given is average for 3 units.

### SMALL FRUIT AND GENERAL FARMS.

The crop area in the first two divisions of Table 13 is practically equal and the operators have the same number of live-stock units to look after. The small general farmer grows twice as much grain as the fruit grower, and has more than a third of the crop area in sugar beets, which are conspicuously absent on the small fruit farms. The orchardists have nearly a half of the crop area in fruit and more than an eighth in fruit not yet bearing. The men in group two have but little fruit. A few grow more than is needed for the family, while half of them grow none whatever. The general operator replaces fruit with sugar beets. The men on the smaller fruit farms use 17.2 man-months to care for their enterprises, or a fifth more than those on the small general farms. The difference in labor used represents almost entirely labor hired by the day or by the piece, and it alone is sufficient to account for the difference in labor income of the two groups. The orchardists have 10 crop acres per man and the general farmers 11.7. The number of work horses and crop acres per work horse is substantially the same in both divisions. The men in the first group receive a labor income of $17.52 for each month of man labor used, while those in the second receive $26.48, or a half more. The latter uses less labor on the same size of farm, and to considerably greater monetary advantage.

### LARGE FRUIT AND GENERAL FARMS.

The orchardists in group three, Table 13, use nearly a fifth more man labor than the general farmers in the fourth division. The latter have somewhat more land in crops, but this is offset by the larger percentage of intensively tilled land in the third classification. The orchardists have slightly more animal units, less than a third of the grain area, and 50 per cent more hay and fodder area than the general farmers. They grow considerable hay in the orchards, which thus often bear two crops, one of which is distinctly stable in character and is a valuable addition to the farm enterprises. Their beet acreage is almost nonexistent, while the men of group four devote more than a fourth of their crop acres to sugar beets. The fruit growers have more than a third of the tilled land in fruit and an eighth in fruit not yet bearing, while the general operators have about a twelfth of their cropped area in fruit and less than a twentieth in fruit not bearing. They have nearly twice as much land in miscellaneous crops as the men in group three. The fruit growers receive a labor income of $24 per month of man labor used, or a third less than the general farmers secure ($31.83) with the same size of farm and of business. The difference in the returns for labor is less on the two large types of farms because the large orchardists place more dependence on general crops than do the small fruit growers. The large, like the small general operators, use less labor than the fruit growers, but to greater advantage.

The men operating the large general farms, as well as those on the large fruit farms, pay some attention to live-stock enterprises, cows predominating. Receipts under this head form an appreciable though not a large item.

Only a few of these operators have enough pasture land to keep more than a few cows. The cows, which are usually bred to freshen in the spring, gather virtually all their feed until late in the fall, and owing to the character of the pasture (as well as the quality of the herds generally seen) the milk flow is not heavy and the lactation period is somewhat restricted.

Some orchardists keep one or more brood sows and feed the drop and cull fruit to the swine to good advantage.

### SMALL POULTRY FARMS.

Four of the live-stock farms in group 3, Table 1, are poultry farms on very small areas. They are presented in column 6, Table

13. They averaged 8.9 acres in size, with 8 tillable acres, all in crops. Three of them averaged $483 in labor income. That of the fourth is not averaged, as he had a very profitable business, exceptionally well handled, and would raise the labor income for the four to a very misleading figure. Few men could hope to approximate his income, and many who have gone into the business carelessly as a result of his success have failed miserably. The significant fact in this group, however, is that with a quality of poultry business which many farmers could reasonably expect to attain, these three operators made a labor income almost two-thirds larger than did the small fruit growers, and more than one-fourth larger than did the small general operators. It is also significant that the men in all three small groups had the same size of business and that there was not much difference in the amount of labor used per farm. The poultry men netted nearly twice as much per month of labor used as did the small orchardists ($32.54, as compared with $17.52), and nearly a fourth more than the small general farmers ($32.54, as compared with $26.48).

### DAIRY FARMS IN COMPARISON WITH LARGE FRUIT AND GENERAL UNITS.

The dairy farmers in Table 13 have considerably greater acreages in crops than the large orchardists and general farmers, while their total areas average twice as great as the average of the other two groups, the difference being due principally to the land used as pasture. The dairy farms have 3.5 times the number of animal units as the above two groups average (31.6, compared with 9), and 17 of these animal units are milch cows. The dairymen grow 12 acres of grain, 30 of hay, and 10⅓ of beets. Their orchard enterprises are largely for farm consumption, and the crop sales include little but beets, a little hay, milk or dairy products, calves, and considerable pork from farms producing butter. They use one-half more labor than the large general operators, and one-fourth more than the large orchardists. They grow one-tenth more crop acres per man than the fruit growers and one-fifth less than the general farmers. In addition, however, the regular labor used cares for about 15 animal units per man, and with the aid of the manure dropped secures a third larger yield per acre of grain, a ninth larger yield of hay, and a fifth larger yield of beets per acre than is secured by the operators in the other two groups of large farms. The men in column 5, Table 13, therefore, get more work done per unit of labor and the work is more efficiently done than is the case with these other two farm types. Their labor income per month of labor used is nearly twice that of the large orchardists ($46.41, compared with $24) and nearly 50 per cent greater than that secured by the general operators ($46.41, compared with $31.83).

The typical dairy farmer virtually adds 45 acres of pasture to the large general farm, curtails the grain area by a fifth, triples the hay area, slightly curtails the beet area, puts on nearly four times as many animal units, and runs the farm with 10 months' additional man labor. The only period when there is much spare time from field work and labor on live stock is during July and August. That period is generally used in laying tile drain. The weakest point in the system is the frequent presence in the dairy herd of cows which do not pay their way. Many farmers are remedying this as rapidly as possible.

### DAIRY FARMS COMPARED WITH SMALL FRUIT AND GENERAL UNITS.

The dairymen grow twice as many acres of crops per man as do the small orchardists and their labor income per month of labor used is 165 per cent larger ($46.41, compared with $17.52). In comparison with the small general farmers they grow twice as many acres of crops per man and their labor income per month of labor used is 77 per cent larger ($46.41, compared with $26.48). The yield per acre of grain and hay secured by the dairymen is nearly a tenth larger than the average of the first two groups in Table 13, while the yield per acre of beets is a fifth larger than that secured by the small operators. In other words, these representatives of the "little farm well tilled" are not tilled as well as the dairy farms. It should be noted in this connection, however, that the poultry men in group six secure a slightly larger yield per acre of grain and beets, and a fourth larger yield of hay than is harvested by the dairymen. This, of course, is chiefly due to the large amount of highly concentrated manure which is available to the poultry man.

### EFFECTS OF SIZE OF FARM AND TYPE OF FARMING.

The large orchardist secures a net return per month of labor which is $6.50 greater than is received by the small fruit grower, while the large general farmer secures a net return which is only $5.50 larger than that of the small operator on the same type of farm. The reason for the slightly smaller margin of advantage for the large general farmer is probably that both large and small operators of this type grow crops which suit the local marketing conditions, and the man on the small unit specializes to a greater extent on the most profitable crop, while the larger orchardists supplement their bulky, perishable special crops with considerable areas of general crops which have a ready market at home, a practice which the small orchardist can not follow. With larger farms, which utilize the family labor more fully, particularly in caring for standard field cash crops, the large orchardist would logically be expected to do relatively better than the small, as compared with the large and small general farmers, because the limited area of general crops grown by the small orchardist barely fills the family flour barrel and the feed bin for the few head of live stock kept.

TABLE 14.—*Labor requirement of crops.*

[Days per acre.]

MAN-LABOR.

| Crop. | Winter, 96 days, 46 available. | Mar. 1 to May 1, 60 days, 35 available. | May 1 to July 1, 61 days, 42 available. | July 1 to Sept. 1, 62 days, 50 available. | Sept. 1 to Nov. 1, 61 days, 42 available. | Nov. 1 to Dec. 1, 30 days, 20 available. | Total. |
|---|---|---|---|---|---|---|---|
| Strawberries | 1.50 | 0.17 | [1] 36.04 | 2.67 | | | [1] 40.38 |
| Raspberries | 1.50 | 8.17 | 7.33 | [2] 44.00 | | | [2] 61.00 |
| Peaches | | 6.24 | 1.75 | 3.13 | [3] 22.00 | 0.50 | [3] 33.62 |
| Prunes | | 5.88 | 3.20 | .88 | [5] 22.00 | .50 | [5] 32.46 |
| Pears | | 5.67 | 2.25 | [6] 4.38 | [6] 9.50 | | [6] 21.80 |
| Apples | | 4.92 | 1.75 | 3.28 | [7] 14.00 | | [7] 23.95 |
| Alfalfa | | .17 | .83 | 1.03 | .83 | | [8] 2.86 |
| Canning peas | | 1.54 | 4.50 | 3.50 | | | [9] 9.54 |
| Small grain | | .82 | .35 | 1.38 | | .67 | [11] 3.22 |
| Snap beans | 2.00 | 1.00 | 1.94 | [12] 26.25 | | | [12] 31.19 |
| Tomatoes | 1.50 | 2.10 | 5.07 | [13] 15.67 | [13] 12.00 | 1.00 | [13] 37.34 |
| Potatoes | 1.50 | 2.90 | 2.09 | 1.15 | [14] 4.00 | 1.00 | [14] 12.64 |
| Onions | 1.50 | 3.17 | 5.84 | 2.67 | [15] 21.20 | 3.66 | [15] 38.04 |
| Sugar beets | 2.00 | .97 | 3.97 | 1.75 | [17] 6.25 | 1.00 | [17] 15.94 |

HORSE LABOR.

| Crop. | Winter. | Mar. 1 to May 1. | May 1 to July 1. | July 1 to Sept. 1. | Sept. 1 to Nov. 1. | Nov. 1 to Dec. 1. | Total. |
|---|---|---|---|---|---|---|---|
| Strawberries | 3.00 | | 5.67 | 0.50 | | | 9.17 |
| Raspberries | 3.00 | | 1.67 | 6.00 | | | 10.67 |
| Peaches | | 2.81 | 1.67 | 1.50 | [4] 5.00 | 1.00 | [4] 11.98 |
| Prunes | | 3.14 | 3.28 | | 6.00 | 1.00 | 13.42 |
| Pears | | 1.67 | 1.33 | 1.00 | 3.00 | | 7.00 |
| Apples | | 2.50 | 1.00 | .80 | 8.00 | | 12.30 |
| Alfalfa | | | .95 | .95 | .95 | | 2.85 |
| Canning peas | | 2.63 | 4.00 | 4.00 | | | [10] 10.63 |
| Small grain | | 1.30 | | .73 | | 1.33 | 3.36 |
| Snap beans | 4.00 | 1.67 | 1.53 | 3.00 | | | 10.20 |
| Tomatoes | 3.00 | 1.27 | 2.28 | 4.75 | 4.00 | 2.00 | 17.30 |
| Potatoes | 3.00 | 2.47 | 1.08 | .25 | 4.00 | 2.00 | 12.80 |
| Onions | 3.00 | 1.33 | .50 | | 3.20 | [16] 7.34 | 15.37 |
| Sugar beets | 4.00 | 1.60 | 1.53 | .50 | [18] 6.15 | 2.00 | 15.78 |

The figures in the above table include extra labor, mainly at harvest times, which in all cases, even when done by children, is reduced to the equivalent of man time. This extra labor is as follows:

[1] Extra days man labor, 22.68 in third column; 0.2 in other columns.
[2] Extra days man labor, 34.50 in column 4; 0.50 in other columns.
[3] Extra days man labor, 20 in column 5; 1.34 in other columns.
[4] Extra days horse labor, 3 (hauling).
[5] Extra days man labor, 17 in column 5; 2.28 in other columns.
[6] Extra days man labor, 8 in columns 4 and 5; 2 in other columns.
[7] Extra days man labor, 8 in column 5; 1.50 in other columns.
[8] Extra days man labor, 0.75, evenly distributed at each cutting.
[9] Total extra days man labor, 0.77.
[10] Total extra days horse labor, 0.2 (planting).
[11] Total extra days man labor, 0.80 (at harvesting and thrashing).
[12] Extra days man labor, 22.50 (picking by boys and girls).
[13] Extra days man labor, 18 in columns 4 and 5 (picking, mainly women and children); in other columns, 1.25.
[14] Extra days man labor, 2 (digging) in column 5; 0.9 in other columns.
[15] Extra days man labor, 13.60 in column 5 (harvest, mainly children); 5.33 in other columns, of which 4 are used in weeding before Sept. 1 (done by boys).
[16] Extra days horse labor, 2.67 (hauling).
[17] Extra days man labor, 5 in column 5 (harvesting), 1.97 in other columns includes thinning about June 1 (done by boys).
[18] Extra days horse labor, 3.75 (hauling beets).

The type of farming followed, as well as the size of business, is an important determining factor in the net return to the large orchardist, while in the case of the general farmers size of business is the chief factor in their net returns. The size of business is an important factor in the large net return on the dairy farms, but the type of farming appears of equal importance. Most of the labor used on these farms works longer hours than on the other types, and the labor is performed on enterprises all of which give good returns.

In connection with the study of Table 13 it doubtless will prove of interest to scrutinize Table 14 fairly closely. This table presents a highly condensed digest of the detailed labor requirements of the important crops grown on these farms. By consulting the footnotes a good idea can be secured of the demands on the time of the operator in producing the different crops.

## POSSIBLE MODIFICATIONS FOR GREATER PROFIT.

### ON SMALL FARMS.

It is evident from a comparison of Tables 13 and 14 that the small fruit and general farmers are not fully occupied during the crop-growing season, and the reasons for this also are plainly in evidence. The small orchardist grows but 14¼ acres of crops, of which nearly 3 acres are in apples, as much in peaches, a half acre in small fruits—6½ acres total fruit. The large orchardist, with 50 per cent more labor, cares for three times as many acres of crops, of which more than twice as many acres are in fruit. The small general farmer grows less than one-third as many acres of crops as the large general operator attends to with a little over one-third more labor. The question of the seasonal distribution of labor on these small farms is of minor importance, however, as labor, particularly harvest labor,[1] is quite plentiful in this district, and at the same time these small operators have not enough land to keep them busy except under systems of management much more intensive than would be wise in a region so far removed from the great markets. This is the great weakness with these two groups of farms, the lack of land to operate. It is not always easy to overcome. Only a sixth of the land included in this farm-management survey is rented land, though a fourth of the farmers interviewed rent part or all of the land they operate. With the land area as limited as is at present the case, the problem is to make the most of what is at hand and to grow as much as possible of the most profitable crops which are adapted to the region and its market facilities.

The typical small general operator in the Provo area, therefore, has to concentrate as far as possible on crops which give a high return per acre and on crops which can be marketed locally. As the market for canning crops (tomatoes, peas, and snap beans) is somewhat limited in this area, the sugar beet is left as the mainstay for most of these farmers. Many of them specialize on beets, producing little else for sale. When they can secure sufficient manure, many of the larger operators do the same. Some operators even omit alfalfa from their rotations and grow virtually nothing but beets and grain. The grain furnishes food for man and beast, sometimes brings in a small addition to the cash income, and enables the operator to trade the straw with town dwellers for equal volumes of manure from the town corrals. Manure needed for beets in addition to the farm supply and that secured as above is bought for about 25 cents per ton, loaded and hauled by the buyer. The manure keeps up the beet yield, and the operators apply enough to secure 16 or more tons per acre in most years. These men can concentrate on beets in this way because of the ample labor supply. Few farmers have difficulty in securing extra labor when needed for blocking and thinning and for harvesting the beet crop. The operator can grow nearly as large an area of beets as his supply of regular labor can perform the regular operations for, such as hoeing, cultivating, etc., or as he has land and manure for. These men are doing the logical thing in an area where there is plenty of labor, the market is sure, and the land area is limited. They buy the hay needed. Their system is sound as long as they do not crop with beets continuously, until trouble with beet diseases cuts down the yield per acre. The limiting factor in their system is the supply of manure.

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[1] The only important exception to this labor abundance is in seasons when peaches ripen with unusual rapidity. Some orchardists then have some difficulty in securing enough peach pickers.

More men would follow such a system as above if they could get the manure. It would seem probable that many more of them could follow such a system with the present supply of manure. In the absence of a good market for canning peas and snap beans, which would permit a greater relative concentration on beets because of the fertility they leave in the soil, reliance could be placed on edible dry beans. This crop leaves a large amount of immediately available fertility behind it. It also furnishes a considerable amount of roughage which is highly valued for live stock in bean-growing sections, particularly when fed with some good hay. The small farmer's bill for hay would be markedly decreased or possibly almost wiped out by growing a few acres of beans, and the same amount of manure would suffice for a much larger area of beets. At the same time, the small amount of extra labor needed for beans comes largely at a time when such labor is in relatively small demand. This fact, of course, is of more importance to the larger operators, and will appeal quite strongly to orchardists who have to pay a heavy bill for extra labor every year, extra labor used on crops which in many cases give but small net returns. The home market for beans would be quickly supplied, but the crop is easily stored or shipped, and is of sufficient value for its bulk to warrant a long shipment to market centers.

When a man is able to rent additional land, or owns a farm which approximates the upper limit of those in groups 1 and 2, Table

13 (27 acres), his problem is simpler, as with 22 to 24 crop acres he can retain alfalfa in his rotation and still concentrate on beets. The manure supply in this section is not specially large and many men do not care for the labor of hauling it in the winter, preferring to grow the forage crop. The alfalfa should be plowed up at intervals of not longer than four years to give fresh land for beets and thus minimize the danger of beet diseases. Whether the alfalfa is grown or not, it would pay to disk the stubble land as soon as the grain is stacked and sow a suitable green-manure crop, to be turned under late in the fall or in the following spring.

The small orchardist has a more difficult proposition than the general farmer. He is usually located on the benches, where the sugar beet does not take as kindly to the soil as on the richer bottom land. Many orchardists are turning to other enterprises, but this is not readily done when a large proportion of the land is in bearing fruit. The men who are striving to change are primarily the peach growers, as pears are distinctly a profitable crop with a fair yield and good care, prunes are next to pears for profitability, and apples usually are well ahead of peaches. Some men in a position to do so would do well to put in a small area of strawberries and raspberries, as these crops are largely supplementary to tree fruits, and give a good return per acre with a moderate yield (250 or more crates per acre). (See Pl. IV, fig. 2.) There would be something of a labor congestion before May 1 unless part of the orchard were summer or fall pruned, but on these small farms this labor conflict would not be serious. Any man setting out small fruits should take every precaution to secure healthy plants. It should be borne in mind, however, that the logical market for small fruits in Utah is in the intermountain country itself, and that overproduction would follow a marked extension of the area in these crops.

The peach grower would do well to cut out alternate rows of trees rather than chop them down indiscriminately, and set out prunes or pears in their place rather than small fruit. Should he desire to eliminate that part of the fruit area, and the farm were well situated for the hauling, he could profitably crop the intervals with sugar beets. With plenty of manure the yield is good, and half or more of the former orchard area could be in that crop. The beet harvest does not begin until the peach crop is gathered, and there is no labor conflict. With other tree fruits there is a conflict, but on these small farms this is usually a matter of small importance. Tomatoes also could be grown under the above conditions in spite of a labor conflict during the two weeks of peach harvest. With the labor of women and children as plentiful as is the case here, the only difficulty lies in the hauling, but judging from the experience of men who grow limited areas of both these crops on small units, this would not prove a serious obstacle. Should a good market for canning peas and snap beans develop, these would be excellent enterprises for the orchardist, as the returns are high with fair crops ($40 to $45 per ton), and the labor is almost entirely noncompetitive with that for tree fruits.

When the farm is not favorably situated for hauling beets it would pay the small orchardist to rent land (preferably bottom land) which is so situated, in order to supplement the balance of the farm. He would be handicapped by the distance of the rented land from the farmstead, but a few acres of beets or other crops suggested would be a profitable addition to the farm enterprises. Although the farming of land in widely scattered fields is not conducive to the best farm management and should be discontinued when practicable, under some conditions (and within reasonable limits) such a system is preferable to the operation of a unit too small for profitable management.

A valuable addition to the enterprises of the small farmer, whether orchardist or general operator, should be the growing of edible dry beans. The labor on this crop is practically the same as for snap beans, except in the harvesting of the dry crop, which usually occurs the last of August or early in September. The labor need not interfere seriously with any other crops but small fruits. The peach grower could make excellent use of this enterprise by irrigating later than usual and keeping the plants green enough to permit harvesting after the peaches are gathered. The benches around Provo have good air drainage and there would be but slight danger from early frost. No labor conflict would occur with other tree fruits. When well cared for 25 to 30 bushels of beans per acre is a fair yield and $2.50 to $3 per bushel can generally be counted on for the crop. Overproduction can easily occur with beans, but the product can be stored indefinitely and is easily and safely shipped. So far as practicable the small orchardist should supplement his orchard activities with stable enterprises yielding a high return per acre. In most instances he already is overburdened with crops giving uncertain returns.

### ON LARGE FARMS.

The large fruit and general farms present an entirely different problem from that of the small farms. Usually there is enough land to keep the operators fairly busy. The large fruit growers, with a little over a third more labor, care for more than twice as much fruit, bearing and nonbearing, and four times as much land in general crops as is the case with the small orchardists. Their field crops virtually serve as "fillers" for the periods when labor on the orchards is slack, but their labor income could be raised without much expense for other than harvest labor by the addition of limited areas of crops already mentioned. When the fruit harvest occupies most of the fall period, enterprises which require much time then would not do, and this eliminates tomatoes. Beets could be grown if there were much slack after the latter part of September, as their harvest is intermittent. Some of the orchardists find them a very profitable addition to the cropping system when the farm is favorably situated for the hauling. With a good market for peas and snap beans they would make an excellent addition. Under the present market conditions dry edible beans would do nicely. Beans already are grown in very small areas by a few orchardists.

The large general farms use a little over a third more labor than do the small units of this type and grow more than three times as many acres of crops. The intertilled area is 2.5 times as large. Many men in this group, like some in the small-farm group, concentrate largely on beets, and have two-fifths to one-half of the cropped area devoted to them. Their labor incomes average two-thirds larger than the average for the group as a whole. Most of the large general farmers could increase their labor incomes without much extra expense for labor by the addition of enterprises which supplement those already present. There is danger in the combination of beets and tomatoes when these crops occupy a large area because after the first time over the tomatoes are picked continuously and must be hauled every day. If the available teams can not do this during the beet harvest and an extra team can not be hired, that part of the tomato crop which is neglected becomes a total loss. Canning peas and snap beans would make a valuable addition. In the absence of a demand for them dry edible beans are a good filler, as little or no extra labor would be needed and the harvest is finished before that of beets or the last haying begins, and the grain is all stacked before the labor on bean harvest starts.

Some of these general farms have orchard enterprises of a moderate size, usually apples. Owing to the character of the beet harvest, the labor conflict which seemingly results is not of much moment unless the area in one or the other of these crops is unduly large, as the harvesting of each crop is an intermittent activity.

### LABOR IN DAIRYING.

As has already been shown, the dominant type of live-stock farming in the Provo area, and the most profitable type of farming, is dairying. Compared with the other types, the labor used on the dairy farms is much more evenly distributed throughout the year, and this is particularly true of the units which engage in winter dairying. Instead of being practically idle a large part of the time from December until March, the winter dairyman is profitably occupied during that time, while the hauling of beet pulp for succulent feed, and the spreading of manure, also keeps the horses fairly busy. The labor on live stock is heavy until the latter part of April, when the feeding of beet pulp ceases and the stock starts gathering the bulk of the feed on pasture. The time required by the chores decreases perceptibly after the 1st of April, and rapidly after the 1st of May. The third cutting of alfalfa and 40 to 50 per cent of the beet harvest is finished before the labor on live stock becomes especially heavy in the fall, about the middle of October. Thereafter virtually the only field work on the typical winter-dairy unit is the remainder of the beet harvest and the daily cutting of green corn fodder from an acre or two of corn grown for succulent feed to be fed before fresh beet pulp is available (about November 1). With beet pulp available at 50 cents per ton there is no economy in feeding ensilage.

In one locality near Provo winter dairying is followed almost exclusively. The average size of a number of these farms is 155 acres, with 59 acres in crops. A large portion of the cropped area is in alfalfa (28 acres), beets (19.5 acres), and small grain (7.5 acres). These farms have an average of 40 animal units, of which 24 are milch cows and 6 are work horses. The other 10 represent young dairy and work stock, a few pigs, and a few chickens. The operator usually keeps a man by the year, and another from March until December unless he has one or more partly grown boys who can help with the field work in the summer. The boys also help with the labor on live stock throughout the year. The farmers in question have to hire considerable extra labor during beet harvest, and in May when that crop is blocked and thinned. Some exchanging of labor is also done, though very little. From 7 to 9 cows are milked per day per regular man during the crop-growing season. During March the regular men devote about 5 hours per day to field work. From about April 1 to early May 6 hours a day are spent in the field. From early May until the middle of October the farmers calculate on averaging 7 hours of field work a day per man. Extra labor hired puts in the regular field day of 8 to 8.5 hours. From the middle of October until the first of December the regular men do not average over 6 hours a day in the field. Thereafter the field work ceases and the second man, if more than one be hired, is laid off until March. From about November 1 to April 1 the total chores and labor on live stock, including hauling the milk not over 1.25 miles, require from 6.5 to 7 hours of man labor per day for each 10 cows in the dairy herd. From the middle of May until the middle of October this work consumes 4.5 to 5 hours per day. The number of cows in the different herds varies from 20 to 28, and the number of animal units from 32 to 50. During the winter the young stock is nearly always fed in the barnyard, and in the summer they require but little attention, as they are on pasture all the time. The operators start work at 5 to 5.30 in the morning the year round, and finish the evening chores at about 7 o'clock. Each regular man looks after 12 to 16 animal units and on the average gets in at least three-quarters of a day in the field from April 1 to November.

## POSSIBILITIES OF AN EXTENSION OF LIVE-STOCK ENTERPRISES.

### DAIRYING.

Although the Intermountain region is, as a whole, somewhat sparsely settled, quite a field remains for an extension of live-stock enterprises. The demand for market milk is just about supplied at the present time, and the only period when there is an appreciable scarcity is in September. On the other hand, the local demand for creamery and cheese products is far from supplied. A rapid growth is now taking place in the creamery and cheese factory industry of the State and the output of the Utah factories is of very good quality. After the home product approximately meets the demand it seems only reasonable to look for further extension in the business, as cool or cold nights, abundant cold mountain water, and soil naturally adopted to alfalfa give the farmers in this region an appreciable advantage over dairymen in some other sections. It should be borne in mind, however, that the high freight rates which the Utah producers will have to pay to reach the large markets will necessitate the maintenance of a very efficient selling organization and a uniformly high standard of product to enable him to compete successfully with dairymen in regions more centrally located.

With the existing market for dairy products, men with moderate area of pasture land would be able to increase their labor incomes quite easily by the adoption of dairying if based on good cows. Although unusually efficient men with exceptionally good cows might be able profitably to adopt this enterprise entirely on the high-priced irrigated lands of this area by the use of artificially seeded pastures intensively stocked, the very moderate price received for the raw product (about $1.45 or less per hundred pounds for milk and 30 cents or a little better for butter fat) suggests that such a system of management might be unwise for most operators. When the high-priced irrigated land is farmed in connection with the cheaper pasture areas, however, a happy combination is found for the dairyman. For this reason the successful dairy farms in Provo district are located along the lake, where large areas of relatively cheap pasture land are found. These farms are fairly large, averaging 119 acres in size, of which a half are in crops.

Some men are doing fairly well on small farms, but none of these who make dairying a prominent enterprise operate less than 30 acres of land. This is nearly twice the average area in the first two groups of Table 13, the small fruit and general farms. In parts of the State where considerable surpluses of grain and hay are produced there may be quite a field for the development of the smaller, more intensively stocked dairy units in the hands of very capable men, but owing to their lack of land, particularly of pasture, it does not seem practicable for most men on the smaller farms in the Provo area to engage in dairying.

It has been suggested that some men on the smaller farms might find it profitable to stock intensively with good cows and to dispense with pasture altogether, operating on the soiling system as is done in parts of Europe. To be profitable, such a system calls for high-producing cows, high-quality land, a high-priced product, and cheap labor. The last two requisites are not present in Utah. This plan might answer for a time with properly equipped men who have large families and little work for the children to do, but the supply of family labor is not permanent, and with present prices for the product the adoption of the soiling system of feeding, and intensive stocking in connection therewith, would appear to be an unwise procedure.

A profitable addition to the farm enterprises for men who sell butter fat, and for many who do not engage in dairying, would be the production of pork. The market for pork in Utah is considered nearly as good as within 200 miles of Kansas City or Omaha. When beet tops are available they make an excellent feed for swine, and not much else need be given from beet harvest until Christmas, or even until the latter part of January. The cheapest feed in summer and early autumn is alfalfa pasture. Some men are making pork on this system to excellent advantage.

## POULTRY.

The most feasible live-stock enterprise for the small farms would appear to be poultry. The market for eggs is not yet fully supplied. Specialized poultry farms are sometimes quite profitable in favorable localities when the operator secures good egg production and high prices, but otherwise they rarely are profitable as a specialty. To have high egg production at the time of high prices requires good management, considerable experience, and a close attention to minor details of feed and care which does not appeal to many men. Therefore any expansion made in the poultry business should in most cases occur on farms of a more general character where the fowls are made distinctly a side line, where the necessary care is a minor item, and a large part of their keep is obtained from what otherwise would largely be wasted.

## RANGE CATTLE.

When it is feasible, an enterprise which would appear to make a good addition to the farm business as a whole is a limited adoption of the range-cattle industry. Some men in the Provo area run cattle on the Wasatch and Uinta National Forests, or on other range back in the mountains, wintering them on their farms. As a result of agricultural settlement, however, the area of the range has been slowly decreasing all over the State. A striking instance of this was the reclamation of a large part of Provo Bench subsequent to 1900. Until then this land was largely a cheat-grass and sage-brush desert used mostly for sheep pasture. Now it is preponderantly orchard land. The more recent encroachments on the range are in the mountain valleys, where the land is dry farmed and to some extent devoted to irrigated farming for general crops, with cattle or horses as an important enterprise. At present the National Forests in Utah are stocked to their full capacity, being more intensively grazed than those of any other State. Their carrying capacity shows a steady increase under the system of management in force, but this, of course, is a matter of slow growth. Many stockmen own considerable areas of range land, which is stated to be stocked to its capacity in most instances, as is the case with other privately-owned range. Most of the grazing land owned by the State lies within the National Forests and is fully stocked.

### DETAILS OF THE RANGE-CATTLE ENTERPRISE.

The Utah farmers who at present make live stock (principally cattle) an important side line in the farm business run the stock on the range for 5.5 to 7 months, depending on the season and the locality. In the northern part of the State the range season usually lasts 5.5 to 6 months. The stock is driven into the mountains between April 1 and May 1 in most years, and the animals start for the valleys from early September until the middle of November, when in the majority of cases practically all that are wintered on the farms are off the range. Relatively few men who have cattle as a farm enterprise intentionally keep any of the stock on the range the year round.

When the animals reach the bottoms in the fall, good yearlings (16 to 18 months old) weight from 700 to 800 pounds per head, sometimes more. The 2-year-olds usually weigh from 850 or 900 to 1,000 pounds, and the 3-year-olds from 950 to 1,100 pounds per head. The stock cows weigh from 900 to 1,100 pounds though some come out quite fat at 1,200. They are sold practically always by the ninth year, and in general any cow coming out fat not having had a calf, is disposed of at once. Most men reckon on disposing of 6 to 7 mature animals a year (2.5 to 3.5 years old) for every 10 stock cows. Most of the animals are Shorthorn and Hereford grades; though there is some Devon, in a few cases Jersey blood, and occasionally evidence of Holstein, though these breeds are comparatively rare with range stock. The smaller stockmen do not supply bulls, depending on those of the larger owners to serve their cows. Most men make two trips with salt in a summer, a day being needed for each trip. They give each head from 3 to 4 pounds of salt during the range season, or half to two-thirds as much as the animals are reckoned to need.

Most of the range cattle marketed each year are sold directly from the range or after a short time on pasture in the irrigated bottoms. As the animals come out of the mountains they are put on fall pasture until enough fat stock is on hand to sell. Those to be sold, of course, are given the best pasture if there is any preference. Alfalfa or beet tops or a combination of these two is preferred for such stock. Many men hire alfalfa pasture for $2 per acre, beet tops for $1, or the two for $1.50 per acre. Some men rake and haul the beet tops and feed them on sod land, though this is not usual. Most stockmen are of the opinion that the animals are better able to gather their own feed. A 3-year-old steer on full beet-top feed eats from 135 to 175 pounds a day and wastes 30 to 50 pounds. A 20-ton beet crop leaves 8 to 10 tons of tops and crowns on the ground, and an acre is reckoned to carry three 3-year-old steers for about a month. Beet tops to steers for fall sale makes them very fine and sleek, especially if they are grazed on alfalfa. The farmer, if he hauls the tops, aims to give 40 to 60 pounds per head per day. They are an especially good feed for cows to be turned off in the fall, and considering their food value they are priced at a figure which seems ridiculously low. Dry-land grain stubble is often rented for fall pasture for 50 cents per acre, and irrigated grain stubble for $1 per acre.

The fall price for fat stock is usually at the rate of 6 to 6.5 cents per pound, though most animals are sold by the head, a practice which should be abandoned. Steers with an extra good finish command 7 cents at times. Stock sold fat in the spring usually brings 6.5 to 7 cents unless the market is below normal. The bulk of the cattle from northern Utah are shipped to the coast, while those from the southern part of the State are sent east to Omaha or Kansas City. The best time to market stock is stated to be in June, but this necessitates heavier winter feeding than most farmers care to give. When this is done, the animals are put on good early range until June, if such range is available. There are a few farmers who make a practice of feeding heavily through the winter for spring sale, and at a number of places large numbers are so fed on beet pulp and alfalfa hay, but not as a farm activity. Men with more feed than they need often buy up yearlings and 2-year-olds for winter feeding and sale as range feeders in the spring if they can not get the necessary range themselves. Some men make this phase of the business something of a speculation.

## WINTER FEEDING OF STOCK CATTLE.

### FEED REQUIREMENTS.

The winter feeding season ordinarily lasts from 4 to 5.5 months, but sometimes 6 months, depending on the locality and the weather. Stock cattle are given free run of the fields all winter by virtually all farmers. As a rule, only the calves are given an appreciable amount of shelter. Generally they are put in a field or yard by themselves, usually with a shed more or less inclosed and are more carefully looked after than older animals. Most men find that it does not pay to permit the calves to get stunted through neglect during the first winter, and special attention is given them to secure more growthy stock for sale the second or third year. Very often the calves are fed on alfalfa hay, from five-eighths to three-fourths of a ton per head, depending on the severity of the winter and the length of the feeding season. The operators find that this pays. Others feed them the finer wild, or slough hay, but they do not get as good results. In the northern part of the State the full winter feed is not usually given until the first of December or the latter part of November. A couple of loads of wild hay are fed per week to each 80 to 100 head for 2 or 3 weeks previously while the stock is picking up most of their feed in the open fields. As one goes southward the full feeding period is delayed, until in the vicinity of Provo it does not begin until about the middle of December.

With a feeding period of 5 to 5.5 months (and not many farmers in northern Utah have to give full feed for more than 5.5 months except in occasional winters) a man calculates to feed about 1.25 tons of wild hay to the yearlings, not quite 1.5 tons to the 2-year-olds, and 1.5, or a little more, to the stock cows and any backward 3-year-olds which may have been kept over. In severe winters when the weather stays crisp and cold for the greater part of the time, the above amounts are exceeded somewhat. In addition to the hay the stock is fed all the straw they will eat. Most feeders lump the yearlings and 2-year-olds with the older animals and reckon on 1 to 1.5 tons of wild hay per head in the herd when they have a season of 5 to 5.5 months full feed. The amount actually fed varies with the supply on hand, the proportion of yearlings to older animals, and the season. In sloppy weather the stock does not eat as freely as when it is cold and crisp. The aim is to feed no more than the animals will clean up, but to keep them growing.

When plenty of warm water is handy a man can winter his cattle with very little hay, and they can be brought through to spring in fair condition, but this management is not favored if it can be avoided. A ton of barley straw, if not too coarse, or the same amount of wheat straw, is reckoned to be equal to about a third or two-fifths of a ton of wild hay, and a ton of oat straw to be worth one-half to three-fifths of a ton of this hay for feeding purposes. Alfalfa hay is deemed twice as good a feed as wild hay. In northern Utah slough hay sells for $4 to $4.50 per ton, and straw for $2.50 to $3 and alfalfa for $7 or $8 to $10 per ton in most years. The buyer does his own hauling. The stock is often given free access to the straw stack, but they then waste more than they eat. The better farmers, when they wish to use their straw to good advantage, haul it to the fields and spread it out on the snow. Hay is practically always fed in racks.

### LABOR USED IN WINTER FEEDING.

The daily duty of a man and team in winter feeding varies greatly with the conditions under which the work is done, as well as with the man. When the stock is in adjacent feed lots within a circle of half a mile, with free access to the straw stacks, and the hay does not have to be hauled over three-fourths of a mile, a man with a team is expected to feed 250 to 300 cows, calves, and older stock through the winter. It takes a very good man to feed 300. Basket racks are used altogether for the hauling and not over 1,500 pounds are taken per load. When the straw is hauled and spread on the snow under the above conditions one man feeds 150 to 200 head. With a haul of up to 2 miles for straw or hay, the straw being spread out, one man can not feed more than 150 head, and he has to be an active hand to do as much. The ordinary man rarely feeds more than 100 to 125 head under these conditions. One operator fed 130 cattle (of which 30 were calves) and 40 horses in a 9-hour day during the winter of 1914–15. Part of his hay and straw (which usually was spread on the snow) had to be hauled 4 miles. He stated that he could not expect to get the same amount of work done with less than two hired men.

### WINTER FEEDING FOR BEEF.

The fact that some operators feed for beef through the winter has been mentioned. This is not done to a very great extent on the Utah farms. Adult animals so fed for spring or early summer sale are given 30 to 40 pounds of alfalfa hay a day, being reckoned to consume 2.25 to 3 tons in a feeding period of 5 months. With the lighter hay feed considerable straw is also given; with the heavier hay ration very little straw is fed. A 3-year-old steer is expected to gain 150 to 200 pounds by spring, sometimes a little more. With alfalfa hay at $10 per ton there is little or no money in this operation. With a gain of 200 pounds, and sold at 7 cents, a 1,200-pound animal brings $84. If worth but 6 cents in the fall at 1,000 pounds, there is a gain of $24 in value. Two and a half tons of hay at $8 to $10 makes a feed cost of $20 to $25 without charging the cost of labor, interest, etc. After allowing full value for the manure, most men do not figure that this activity pays if anything is to be allowed for labor.

### RANGE CATTLE IN PROVO AREA.

The farmers in the vicinity of Provo who are turning to range cattle as a side line are those who own or can get the use of some of the lowland along the lake. This is very good pasture for such stock, and considerable coarse, wild hay is cut for winter feeding. To date this low shore land does not appear to be used to its full capacity. Men who have recently adopted range cattle as an enterprise have bought the stock and grazing permits of others or have bought or leased range land outside of the National Forests. In the nature of the case, only in rare instances do range cattle constitute a practicable side line for the small operators unless they can secure the use of some of the low lake-shore pasture. It should be noted, however, that the labor required by range cattle is almost entirely supplemental to that in crop growing. General farmers able to adopt the above enterprise thus have work for the idle winter months when their time is not worth a great deal. With other conditions favorable, a man could well afford to price his winter labor on cattle at a low figure.

### BABY BEEF.

A promising enterprise in connection with the cattle enterprise would seem to be good feeding and care of the calves for baby beef. With abundant alfalfa hay and some grain the first winter the animals should be in fine shape for sale early the following summer, or even in the second fall from very good range. The increasing demand for this class of beef and the high price received for it merit close attention from the Utah farmer. Disposal of stock in this way will vastly increase the capacity of the range for stock cows, and nearly or quite as much is secured for good baby beef as for 2-year-olds under the present system. An 800-pound 2-year-old steer at 6.5 cents per pound brings $52, while baby beef made under the above system sells at 14 or 15 months for around $50 per head. In this enterprise good grade cows should be used, and a pure-bred bull. Men now making baby beef have the calves come in March or April, wean them in September or October after spending the summer on fairly good pasture, and then place them on a feed of alfalfa hay and a mixture of barley and oats. The grain feed is gradually increased until by the following May each animal receives from 6 to 10 pounds per day. They are sold in May and June. The receipts per cow in the breeding herd are practically twice as large, and the money is turned over twice as fast on the same size of investment as when the beef is made on the range and sold at 2½ years of age. Although the feed the first winter costs more than in the old system, the expense up to the time of marketing the product is less. In the present condition of the range industry in Utah such a plan as the above seems the only way out if more operators are to engage in that enterprise as a side line. Such an enterprise forms a valuable addition to the farm business in the hands of a capable operator who can make use of the range.

## UNCERTAIN MARKETS AND HIGH TRANSPORTATION CHARGES.

The outstanding fact in irrigated agriculture in Utah is the dependence of a large proportion of the farmers on a distant and extremely uncertain market for the disposal of a bulky and perishable product. This has been especially true in the past 10 years, when the orchard area, particularly the peach area, has been greatly increased. A considerable percentage of the peach orchards are on small farms, less than 27 acres in size and averaging less than 18 acres. Under the existing market conditions dependence primarily on fruit by the operators of small farms in this region (and other sections similarly situated) is not safe. This statement applies with added force to the small peach grower. The great weakness with the peach crop lies in the fact that it reaches the market usually in the same week as does that from southern Michigan. The Michigan growers have a big advantage in their lower freight charges. Their crop must be poor or a failure before the Utah growers are able to make much profit. An uncertain market, uncertain crops, and high shipping costs are a severe handicap to the Utah orchardist.

The uncertainty of the market for Utah fruit is characteristic of that for all perishables. The Office of Markets of the United States Department of Agriculture is making rapid progress in its work on the markets for perishable products, but however great its success the other weak points in the system of the Utah orchardist will persist. Although the small-fruit grower who does not depend on peaches is less precariously situated than his neighbor, all the small orchardists are operating with a factor of safety which is entirely too low. In case of crop or market failure they have little else to depend on. Owing to a late freeze the fruit crop in Utah Lake Valley in 1915 was almost a total failure. The small operator suffered accordingly.

Because of the high transportation charges,[1] the operators in the Intermountain country who ship to distant markets should rely so far as possible on concentrated products of a high value for their bulk. In former years when little but beef, mutton, and wool was shipped from the State, the conditions of the market were quite fully met. The possibility of a greater dependence on beef has been indicated. Should an extension of the canning industry give a good market for certain crops in the Provo area the situation of the farm operator will be much improved. The same will result if the creamery business undergoes the expansion which its friends anticipate.

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[1] The freight charges on Utah fruit sent from the Provo area to the Eastern markets and the charges for refrigeration are typical for the State. From Provo the grower pays 90 cents per hundred pounds to get his fruit to Kansas City, Omaha, or Missouri River common points and $45 per car for refrigeration. To Mississippi River common points the freight is 95 cents per hundred and $50 per car for refrigeration. To Chicago these charges are $1 and $55. To Texas common points the freight charge is $1.06 and the refrigeration $60 per car. To the Atlantic seaboard the freight charge is $1.558 per hundred and the refrigeration charge $65 per car. (Freight rates supplied by the Interstate Commerce Commission. Refrigeration charges from Provo were obtained from a large shipper of Utah fruits.)

The average gross weight per packed bushel of apples from Utah County is 52 pounds, the container weighing 6 pounds. The average gross weight per box of pears is 51

In either instance the opportunity for diversification in this area would be much greater than at present. In the first case crops of a relatively high value per acre can be grown; to a considerable degree the labor on them will be noncompetitive with labor on enterprises now followed; and within reasonable limits the regular labor at present only partly occupied can attend to all but the harvesting. In the absence of this opportunity possibilities of diversification with the present range of farm enterprises should receive careful attention. A valuable means to this end would be offered by an expansion of the creamery business, and along lines largely noncompetitive with the current activities on most farms where a dairy herd or an enlargement of the existing herd will prove practicable.

The larger orchardists who place considerable reliance on general crops are more favorably situated, particularly those who have only limited areas of peaches and depend more on the other tree fruits, which give better returns. A factor of no small importance in this result is the lower harvesting cost of these fruits. But the operator who utilizes orchard enterprises as an important though not the primary activity, or as a filler to round out the business as a whole, is the one whose system more nearly fits the existing conditions in this region. This would seem to be the only system on which fruit of any kind should be produced by the great majority of Utah growers. The man with a special market for his product or the occasional orchardist of unusual ability, particularly when he grows the more profitable fruits, perhaps can afford to concentrate on orchard enterprises, but he takes a gambler's risk. A man with small or moderate capital can not afford to run such a chance.

## TOWN-DWELLING FARMERS.

A striking fact in Utah agriculture is the number of farm operators who live in town but have their farms at varying distances in

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pounds, the container weighing 5 pounds. A case of peaches averages 21.5 to 22 pounds gross and a case of prunes 26 pounds gross. Usually very little Utah fruit is shipped east of Chicago.

Two bushels of fine Rome Beauties were bought near Provo in the fall of 1914. They cost 62.5 cents per bushel, packed and ready for shipment. They were sent by express to Washington, D. C., at a cost of $1.98 a box and thus cost at the house door $2.505 per bushel. If shipped in bulk the cost for transportation would have been 91.85 cents per bushel. These apples packed 76 and 80 to the bushel, and fruit of similar quality on the Washington market sold that winter for $4.25 to $4.75 per bushel. At fruit stands such apples sold for 10 cents each.

the country. This is in large measure a heritage of the Indian days, when communal settlements were necessary for protection, and a man's land lay outside the stockade in more or less intermingled strips, after the fashion of mediæval European agriculture. Much the same system still holds in parts of Europe, as well as in other parts of the world. When all the land farmed is in one piece, or where the fields are located quite close together, the inconvenience of this arrangement is not so pronounced. But some farmers in this region have land lying in three or four different directions and none of it as close as 2 miles to the home. For example, a man will have a field 4 miles from town in one direction, another field 3 miles away in another, and the remainder as far or farther away in a third. The roads may be so planned that the quickest route to any other field from one in which work is going on is back to town and then out. Under such conditions the time wasted on the road is a serious handicap to successful farm management.

Even with the least inconvenient arrangement, that of having all the land in one block or in neighboring blocks at a distance of 1 or more miles from town, many small economies are not possible. When the fields are widely separated the problem is intensified. Few men in the former situation have their land as close as 1 mile to town. A number from whom farm management records were secured live from 3 to 3.5 miles from the farms, sometimes farther. Each day during the busy season they lose from an hour and a quarter to two hours on the road. They rarely return for dinner in the middle of the day, but when they do so the time lost is doubled.

These men find it practically impossible to use cows, hogs, or chickens as a side line. They therefore buy a pig or two in the spring to fatten for home use and sometimes have a few hens at the house, but their grocery bill for eggs and poultry often amounts to a large sum in the course of the year. A flock sufficient to supply the family throughout the year would be a serious nuisance to the neighbors in town, as would the pigsty. One team is kept in town practically the entire year, as is the cow as long as she is fresh. She is grazed on hired pasture throughout the summer, driven out in the morning and back at night. The milk bill for a large family often is a considerable item after the cow goes dry. The remainder of the stock—that is, practically all the work horses or colts—is kept at the farm. During the winter about two trips are made per week to look the animals over, salt them, and see to the feed. For a part of the winter a considerable portion of the feed is picked up on the beet land if it is not fall plowed or on that part of it which is not so plowed.

The farm garden usually is a very minor enterprise, if present at all under these conditions, and a considerable part of the family living, which otherwise would be raised in spare hours during the summer, is bought over the grocery or market counter. In many cases the quality of the vegetables bought is not as high as that of those raised on the farm. The variety is apt to be somewhat more limited than if grown in a farm garden. As a rule, a smaller quantity of fruit and vegetables is "put up" during the summer for winter use than when a good garden is available. This is an item of far greater importance than sometimes is supposed. A study made by the Office of Farm Management in other sections of the country indicates that about 63 per cent of the food consumed by the farm family is produced on the farm.[1]

When the operator lives in town several miles from the farm he neglects many seemingly insignificant sources of food supply which in the aggregate form a large sum. By no means the least important is the item of animal foods, or animal products consumed. These are the most costly and constitute nearly three-fifths of the total value of the food supply. Often they are conspicuously lacking in the contribution made by the farm to the family living under the above conditions. Considerable money which otherwise would be available for various comforts and conveniences goes for their purchase. On the score of farm management there seems no doubt that the man operating his farm as outlined above is doing so at a serious sacrifice.

There is another side to this question, however. The farmers interviewed readily agreed as to the shortcomings of their system. The wives did the same, but presented facts that put an entirely different aspect upon the case. Many of the families live in town because of the school facilities. In those sections where the country schools have been brought to a high state of efficiency, and they are very numerous in Utah, the farmers habitually live on the farm. Many of those who live in town do so because of the distance the children would have to travel to the country school and because of the better schooling often secured in the town schools. In a severe winter considerable time is lost from the rural school in many cases, particularly by the younger children. Furthermore, the urban conveniences and the urban social advantages have a strong appeal, especially to the wives, and this seems to be as general a reason for living in town as superior schooling, perhaps more general. These wives have a strong argument, as is attested by the fact that they do live in town. When this argument is added to that of the school facilities, their case is strengthened considerably.

It is seriously open to question, however, whether the urban environment, on the whole, is the more wholesome for the children. Certain educators strongly believe that it is not. In general the rural sociologist agrees with the educators. At the same time, the farmers state that they profit but little by the social advantages of the town, and the children less, so far as real advantages are concerned.

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[1] Farmers' Bulletin 635, What the Farm Contributes Directly to the Farmer's Living.

There is small ground for argument on the question of the town school as compared with the country school in some cases, nor on the question of getting the children to school during the winter. The social side of the question is one for the rural sociologist and the specialist in rural organization to study.

The farm-management side of the proposition seems largely undebatable. It seems probable, however, that the greater opportunity more fully to utilize the resources of the farm when it is also made the site of the home, would far more than offset the cost of keeping a horse with which to send the children to school, and the trifling corral rent for stabling the animal while school is in session. Indeed, the main need for the horse is in severe winter weather when the farm draft is largely idle, and probably no extra horse would be required in many cases. The season when the school question is most pressing being that when farm work is most slack, little work other than hauling manure being done then, would seem to indicate the feasibility of the farm operator attending to this chore himself if some other arrangement could not be made.

## IMPORTANCE OF RAISING HOME SUPPLIES.

In regard to more full utilization of the farm resources for direct contributions to the family living, considerable still remains to be done by many of the operators in this section in common with fully as large a percentage of the farmers in other parts of the country. This phase of the farm activities is of peculiar importance to Utah farmers. A considerable proportion of them depend on a distant and uncertain market for the disposal of their products. Good or fair prices received for fruit one year may be and often are offset by poor prices for one or more years. This condition is likely to become increasingly prevalent as the area of fruit at present not in bearing reaches maturity, particularly in regions nearer the consuming centers. The farm garden in particular should receive much more attention, and the surplus therefrom, as well as surplus fruits, should be canned if not adapted to preservation otherwise. Marked improvement is discernible in this regard since the start of Boys' and Girls' Club Work in the State. The work of the Agricultural College and the county agents along this line should meet with the ready cooperation of all the farm operators and their wives. Much can be learned, and valuable economies practiced as a result. By more attention to the above points money which otherwise passes over the grocery counter will be available for other uses, not the least important of which are conveniences for the home, and savings to meet the strain of that lean year, which is sure to recur more or less frequently.

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UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 583**

Contribution from the Office of Public Roads and Rural
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# REPORT ON EXPERIMENTAL CONVICT ROAD CAMP, FULTON COUNTY, GA.

By H. S. FAIRBANK and R. H. EASTHAM, *Highway Engineers*, and W. F. DRAPER, *Passed Assistant Surgeon, U. S. Public Health Service.*

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Without a single attempt to escape, an average of 40 negro convicts were maintained for 10 months in the Fulton County (Ga.) honor camp conducted under the observation of the United States Office of Public Roads and Rural Engineering and the United States Public Health Service. This notwithstanding the facts that the convicts were worked without armed guards, without exceptional conditions as to hours of labor, without special rewards or other unusual inducements to good behavior, and with the camp located near a trolley line and within 11 miles of the city of Atlanta, from which most of the convicts were sentenced, a condition admitted by all competent authorities to be most unfavorable to the successful operation of an honor camp.

With a diet prescribed by the United States Public Health Service, ample in quantity and containing all the properties essential to maintain laborers engaged in heavy outdoor work, the convicts were fed at a cost 9 cents per day lower than that required to maintain other convicts on an unbalanced diet in the same county at the same time.

At a cost of only 6.2 cents per man per day specially designed light and airy portable buildings were provided, and their suitability for the purposes of convict camps was demonstrated by the fact that they were moved at less expense than would have been incurred in moving quarters of any other type but tents.

A supply of pure running water was made available in the camp at a cost of only 1.7 cents per man per day. This result is particularly enlightening in view of the fact that the cost of installing running water systems in convicts camps is thought to be prohibitive by the majority of camp officials.

Waste and garbage were disposed of scientifically by incineration, at insignificant expense; and a system of sewage disposal, including water-closets and a cesspool, was installed and operated at a cost of about one-half cent per man per day.

The sick rate was maintained for six months at less than one-half of 1 per cent; and medicine and medical attention were provided at a cost of 1.6 cents per man per day.

A system of records and reports was installed and operated for six months at a cost of less than $25, and the saving on food alone resulting directly from the employment of the system during the same period amounted to more than $350.

## STRIKING RESULTS OF THE EXPERIMENT.

Taken as a whole, the outstanding results of the experiment demonstrate that cleanliness, comfort, and humanity in the convict camp are not inconsistent with economy and efficiency in the work of the inmates. More specifically the operation of the camp has demonstrated—

That the honor system can be applied to negro convicts without holding out tempting hopes or rewards, extra commutation of time, granting of greater privileges, or awards in money.

That monotonous prison fare can be replaced at lower cost by a scientifically diversified diet that makes for additional bodily vigor and contented mind.

That convicts can be housed in sanitary buildings, provided with clean bedding and clothing at a cost little greater than that of makeshift and insanitary sheds, filthy bedclothes, and unfit uniforms.

That a supply of pure running water can be made available in the camp at surprisingly low cost, with great advantage in convenience and sanitation over the primitive "water-toting" methods followed in the majority of camps.

That insanitary methods of waste and garbage disposal can be replaced by a thoroughly scientific system with little trouble and insignificant expense.

That care and attention given to the diet and the sanitary conditions will yield abundant fruit in a remarkably low rate of sickness.

That a businesslike system of records and accounts can be installed and operated at small expense, and that its worth will be proved by the ease with which leaks and extravagances can be detected and eliminated, and by which a high degree of economy can be effected.

And that the slightly increased cost of maintaining convicts on the higher plane indicated by the above suggestions is fully offset by the increase in efficiency of the working force, so that the cost of work performed is not measurably affected.

These are the most striking results of the operation of the Fulton County camp. The methods by which they were obtained are described in the following pages.

The camp was established as the result of the studies of convict labor for road work conducted in 1914 and 1915 by the Office of Public Roads and Rural Engineering and the Public Health Service. These studies embraced an investigation of conditions, methods, and practices pertaining to the use of convicts in road construction in 21 States, a wide reading of the available literature, and a digest of the opinions of numerous specialists in highway construction, penology, and sanitation. A mass of valuable information was accumulated covering practically all phases of the problem. This material was arranged conveniently and, together with such specific recommendations as seemed warranted by the data in hand, was published as Bulletin No. 414 of the United States Department of Agriculture, entitled "Convict Labor for Road Work."

It was expected that the operation of the camp would establish by actual test and demonstration data of great practical value along several lines, among which might be mentioned the housing, feeding, and management of the convicts. A special type of portable building was designed with a view to determining the practicability and economy of this type in comparison with other camp structures. A balanced ration, under a rigid system of weighing, checking, and cost keeping, was installed to ascertain whether this diet and system would effect economy and promote the welfare of the convict. The honor system was followed in the discipline of the convicts, all of whom were negroes, as this system, although generally recognized to be successful in dealing with selected white convicts, rarely had been applied to the discipline of negro convicts. It was thought that this problem was well worth a practical determination both from economic and humanitarian standpoints.

The plan was first suggested early in the summer of 1915 by representatives of the Office of Public Roads and Rural Engineering to Mr. W. T. Winn, at that time chairman of the Committee on Public Works of the Board of County Commissioners of Fulton County, Ga.

Mr. Winn welcomed the opportunity to improve the methods of handling the convict force and recommended to the board that a cooperative arrangement be made with the Office of Public Roads and Rural Engineering and the United States Public Health Service for the operation of a demonstration convict road camp. The board, consisting of S. B. Turman, chairman; T. J. Hightower, jr., vice chairman; W. L. Gilbert, W. T. Winn, and J. Oscar Mills, gave its approval to the scheme, which was thereupon approved by the State Prison Commission of Georgia. This action by the Board of County Commissioners indicated their earnest desire to improve the condition of the county convict forces and their intelligent appreciation of the possibilities for bettering existing conditions.

## THE PLAN OF COOPERATION.

The county commissioners agreed to establish an honor camp of approximately 40 negro convicts, to inaugurate a system of discipline and to provide suitable portable camp buildings, equipment, materials, and supplies, all in accordance with the plans and recommendations of the Office of Public Roads and Rural Engineering. The county also undertook to supply to the convicts food of the character and in the amount recommended and specified by the United States Public Health Service, and to provide for the management and organization of the working forces, as well as for the keeping of a system of records and reports in accordance with the suggestions of the Office of Public Roads and Rural Engineering. The two Federal bureaus agreed, respectively, to assign an engineer and a sanitary officer to supervise the road work and the conduct of the camp and to be of general assistance to the commissioners in connection with other county camps and road work. To cover the cost of collecting the data desired by the Government, it was arranged that parts of the salaries of the three county officials so employed should be paid by the Office of Public Roads and Rural Engineering.

## THE SYSTEM OF CONVICT LABOR IN GEORGIA.

As the experimental camp was essentially only one unit in the prison system of the county and State, it necessarily was subject to local rules and regulations and to some extent to local customs. Therefore a brief outline of the system in force in the State, and of the usual methods of housing, feeding, and guarding the convicts, will indicate the limitations of the experiment and afford a basis for estimating the value of the results attained.

All males convicted of misdemeanors or felonies in the State, except such felons as are required by law to be kept at the State farm, may be employed upon the public roads by the authorities of the several counties. During the year from June 1, 1915, to May 31, 1916, 412 white and 3,170 negro felons and 217 white and 3,052 negro misdemeanants were so employed. These convicts constitute a State force which the State prison commission apportions, according to population, among the various counties desiring their use. The responsibility of employing and maintaining the prisoners is borne by the several counties under the direction and supervision of the prison commission; and for the guidance of the county authorities the commission has established rules and regulations governing housing, feeding, guarding, discipline, etc. The convicts are under the immediate control of wardens appointed by the prison commission with the concurrence of the county authorities, and the commission also employs supervisors to visit the various counties and inspect the convicts and their work.

Camps established by the counties are of two classes, permanent and temporary. In general, the former consist of wooden barracks frequently located at or near the poor farm. In some of the counties these barracks are well designed and well equipped, convenient, and sanitary, but in many of the smaller counties the sanitary conditions are poor. The quarters in the temporary camps are tents, cages, or cars, and sometimes portable buildings. The sanitary conditions are bad, as a rule, in camps of this character, particularly the cage camps, in which the cages usually are seriously overcrowded.

The beds or bunks provided are varied in character; in a few cases they are metal cots, but more often wooden bunks or individual pallets laid on continuous platforms. Two sheets, sufficient blankets, pillows and pillowcases are furnished to each man, and nightshirts also are provided.

Misdemeanants are clad in suits of striped cloth; but felons are divided into three grades according to conduct, and wear gray, brown, or striped suits according to class. The weight of clothing provided for all classes is adapted to the seasons, and the cloth generally is of satisfactory quality, the clothing in fair condition.

The rules of the prison commission require that food be provided for each convict in not less than the following amounts:

Corn bread without stint, three meals each day except when wheat bread is furnished; wheat bread without stint, three meals each week; three-quarters pound of salt pork each day; one pound of fresh meat or 1½ pounds of fresh fish twice each week; sirup or molasses three times per week; vegetables three meals each week; one cup of coffee for breakfast each day; salt, pepper, and vinegar without stint.

Many of the counties furnish diets of somewhat greater variety and abundance than that prescribed, and the average cost of subsistence in 1916 was approximately 22 cents per man per day.

It is the general practice, except in the case of cage prisoners, to secure all convicts at night by means of leg chains attached to a continuous gang chain and to one ankle of each convict. As an additional safeguard at least one armed night guard is placed on duty in each camp.

The convicts are under constant supervision all day of guards armed with shotguns and revolvers, the number of guards usually approximating about one-tenth of the number of convicts. With these measures in force the number of escapes from the various county gangs represents from 1 to 3 per cent of the number of convicts employed.

Few privileges are accorded, a small weekly allowance of tobacco, and permission to conduct a restricted correspondence with relatives and friends being the most notable.

Punishment is inflicted by withdrawing the privileges and by whipping. Corporal punishment may be administered only by the warden or deputy warden; not over 10 lashes may be given, and it is unlawful to apply the lash to the naked skin. A record of each case of punishment is required by the prison commission, but in spite of all these regulations there is no doubt that the strap is used with cruelty in many cases.

The hours of labor are from sunrise to sunset, with one hour for rest and dinner from November to February, inclusive, one and one-half hours in March, April, September and October, and two hours in May, June, July and August.

The best of the camps of the State are conducted with some degree of economy and efficiency, but in a majority much of the saving possible by the use of convict labor is dissipated by wasteful management, and much of the road work performed by the convicts is of the simplest character, consisting of unsystematic patching and repair of earth, sand-clay, and top-soil roads, which experience has demonstrated can not be done economically by convicts.

The conditions existing in Fulton County at the time of the inauguration of the experimental camp were representative of the best in the State. The county chain gang numbered about 550 prisoners. These were quartered in seven permanent camps in various sections of the county, and one portable cage camp. The latter had a population of 20 men and was known as the "honor" camp. Its inmates were chosen from the other camps of the county as a mark of honor for good behavior, but in no other sense was it an honor camp. The men were locked securely in the cages at night and were worked under armed guards during the day. However, when the experimental camp was opened 17 of its first inmates were assigned to it from this camp and it was known thereafter as the "portable" camp.

All camps and convicts in the county are under the care of a warden and there is a deputy warden in charge of each camp. The road work, however, is done under the direction of the county superintendent of public works, and all surveys and strictly engineering work are done by the county engineer.

## DESCRIPTION OF THE CAMP SITE.

The preliminary arrangements for the experiment were completed and agreed upon in October, 1915, and work on the construction of the buildings was begun November 3. Various causes, including bad weather, the slow arrival of building material, and disputes over right of way of the road to be constructed, delayed the opening of the camp until January 10, 1916. On that day 17 men were transferred to the camp and set to work cleaning the buildings, gathering firewood, and other chores incident to the opening of the camp. On January 12, 16 additional men were selected and sent from several camps, and road work was begun. Not until January 17, however, was the camp manned to capacity. Eight more men were received on that date, thus increasing the population to 41. As the quarters would accommodate only 40 conveniently, one man was returned on the 19th of the month, and from that time the population of 40 was maintained as closely as possible.

The camp was operated under the cooperative arrangement until August 23, 1916. On that date the convicts were transferred from the experimental camp and confined in cages at the county fair grounds. This step was taken by the county commissioners without the consent of the Federal bureaus. It was explained as an emergency measure necessary to complete a race track at the fair grounds in time for the Southeastern Fair, and the commissioners expressed their willingness to hasten the return to the experimental camp and to extend the operation under the cooperative arrangement for a period equal to the time lost, but it was believed by the Office of Public Roads and Rural Engineering that it would be difficult to resume the experiment along the old lines, particularly in respect to discipline, and the cooperation of the Federal bureaus accordingly was withdrawn. However, after the convicts were returned, the camp remained under Federal observation to a certain extent until it was moved to a new site on November 22.

The first work selected for the experimental camp by the county commissioners was the grading of a section of the Powers Ferry Road approximately 2 miles in length. (See fig. 1.) Accordingly, on November 9, 1915, a camp site was selected about 3,000 feet from one end of the road. It was an almost level plot of sufficient area to accommodate all the camp buildings, from which the ground sloped away in all directions. The part selected for the accommodation of the main buildings was free of trees, but was covered with a heavy growth of tall grasses. The part selected for the stable and corral lay to the north of the clearing in a growth of pine trees. These, while they afforded no shade for the quarters, were in such position as to protect the camp effectively from the cold north wind. The soil consisted of about 3 inches of top soil overlying a micaceous clay. It was sufficiently porous to absorb water rapidly and did not become

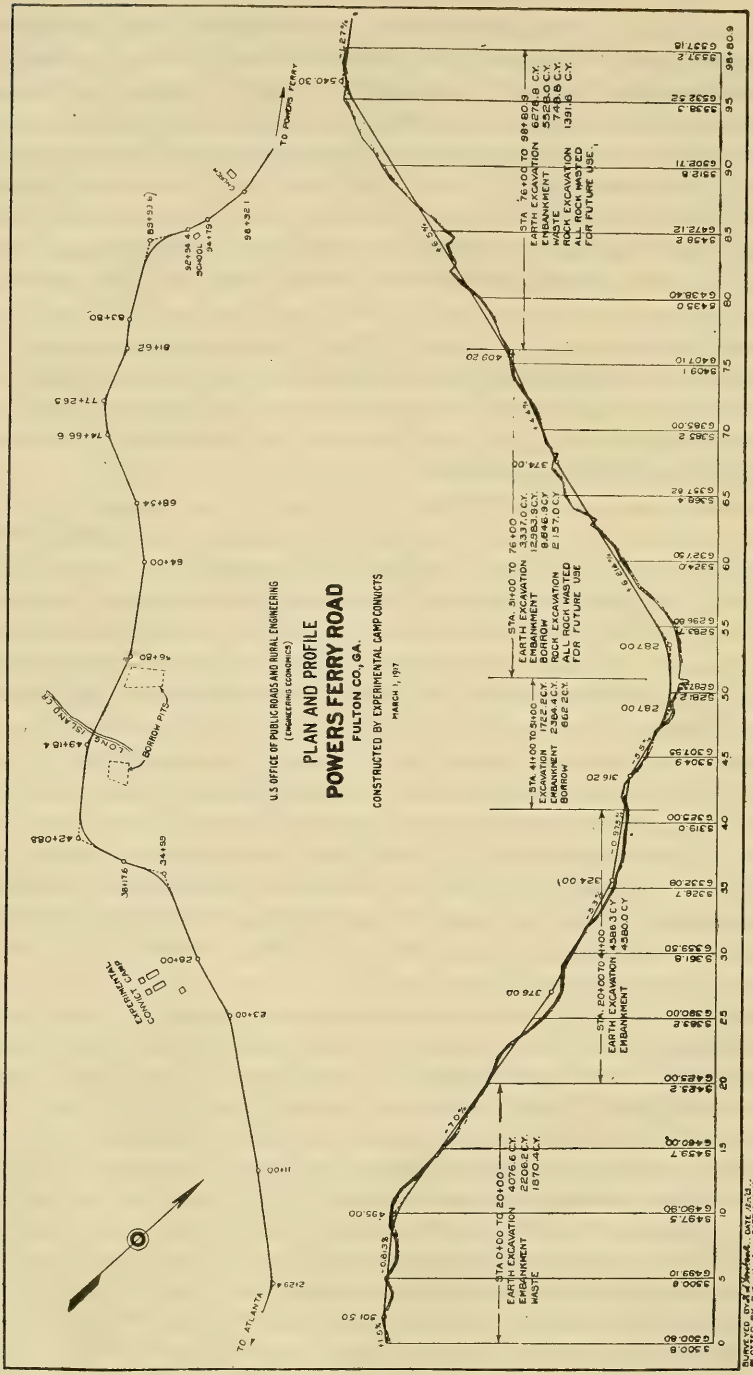

FIG. 1.—Plan and profile of Powers Ferry Road.

muddy except during very heavy rains. Permission was obtained from the owner for the use of the land free of charge, and therefore the only expense for the site was the cost of clearing, laying out a flower bed, and constructing paths and roads. This was done at a cost of $43.50 in convict labor. The site was occupied for 311 days. As there were 7,174 convict calendar days in the first 183 days up to July 10, it is computed that the cost of the site per convict per calendar day was $0.0036. The ground plan of the camp is shown in figure 2.

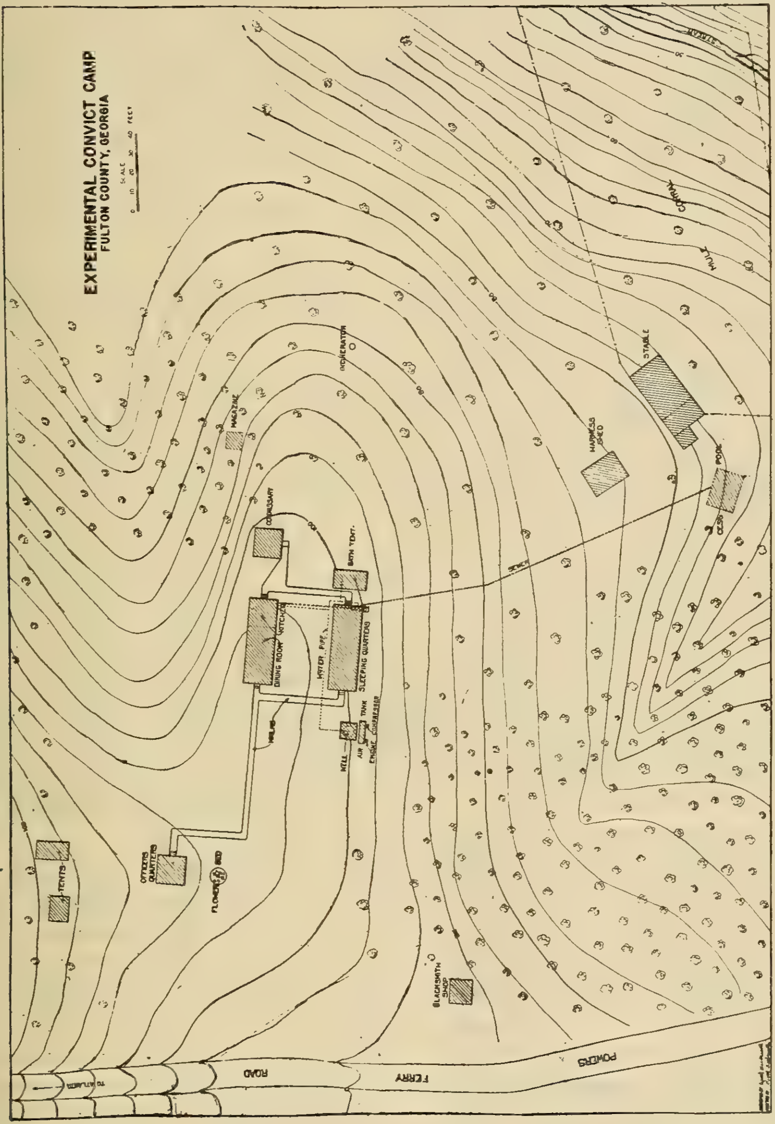

Fig. 2.—Ground plan of experimental convict camp, Fulton County, Georgia.

## CAMP BUILDINGS.

Portable buildings and tents were used for housing the inmates and officers. The stable, harness shed, and blacksmith shop were constructed at the site of rough lumber and galvanized iron. The portable buildings were of a special type designed by the Office of Public Roads and Rural Engineering. The sills, 4 inches wide and 8 inches deep, were cut to the proper lengths to support buildings 18 feet square and were so arranged that any number of such buildings might be joined end to end to form a building 18 feet wide and any multiple of 18 feet in length. They were fastened together at the corners of the building by means of 6 by 6 by $\frac{5}{8}$ inch angles and $\frac{5}{8}$-inch bolts and lag screws. The floor joists, 2 inches wide by 6 inches deep, were set on 2-inch strips nailed to the bottom of the sills, and were spaced 2 feet $2\frac{1}{2}$ inches apart and held in an upright position by means of 1-inch blocks nailed to the sills on each side of them in such manner as to form slots.

The walls were built in sections, each 3 feet $7\frac{3}{16}$ inches in width and 9 feet from floor to eaves. They were built of $\frac{7}{8}$ by 4 inch tongued and grooved material on frames of 2 by 4 inch pieces. Alternate sections were fitted with standard 6-light 38 by 42 inch window sashes and solid wooden shutters of $\frac{7}{8}$-inch tongued and grooved lumber. These were hinged at the top so as to swing outward, and when open they acted as awnings. The wall sections were joined together with $\frac{1}{2}$-inch bolts through the 2 by 4 inch frames, and were held down to the sills by means of $\frac{5}{8}$-inch lag screws.

The floor consisted simply of 6 by $\frac{7}{8}$ inch boards, 9 feet long or equal in length to one-half the width of the buildings. These were laid across the sills and were fastened at their ends only. Along the center of the building they were held down by a batten or floor strip screwed through them to the center joists, and at the sides of the building by the wall sections which rested on them.

The wall sections were tied together at the top by 2 by 4 inch pieces bolted to the top of the sections. When thus bolted to the 2 by 4 inch frame, they formed 4 by 4 inch plates upon which rested the 2 by 6 inch rafters, spaced 3 feet $7\frac{3}{16}$ inches apart, so that they fell directly over the wall joints. The rafters were braced and held down to the plates by means of knee braces of $\frac{1}{2}$-inch round iron rods provided with turnbuckles. They were tied near the ridge by short wooden collar beams, 2 by 6 inches in section, and near the eaves by $\frac{1}{3}$-inch round iron tie rods provided with turnbuckles. The turnbuckles on the two sets of the rods made it possible to allow for swelling and shrinking of the lumber in seasoning, and at all times to keep the walls vertical and the roof as it was designed to stand, at a pitch of 5 inches to 1 foot.

The roof was made in sections of the same width as the wall sections, fabricated of 1 by 6 inch boards nailed to 2 by 4 inch battens or purlins. On the ends of these short pieces of 4 by 4 by ½-inch angle iron were fastened, by means of which and ½-inch bolts the roof sections were attached to the rafters. Each roof section was covered with 3-ply ready roofing, glued to the sheathing, and the joints between the sections were covered, water-tight, with laps of the same material, 12 inches wide, fastened down by roofing nails and cement. The joint at the ridge was covered with galvanized ridge roll, and metal ventilators were set into the ridge at intervals of 18 feet.

All doors and windows were provided with fly screens of galvanized wire mesh.

The complete detailed plans accompanying this bulletin are for buildings similar to those described, but not like them in all respects. (See detached Appendix Plates). The plans show a height of wall of 8 feet, which is regarded as sufficient, and this height was recommended to the county commissioners, but the rules of the prison commission require a wall 10 feet high. The height of 9 feet, which was actually adopted, was the result of a compromise between the height recommended and that required by the prison commission.

Another difference is found in the floor, and is the result of the experience gained in constructing the buildings. Instead of the 6-inch boards which were used, the plans call for ⅞ by 3½ inch tongued and grooved boards which, instead of projecting under the wall sections, are held down at the sides by means of battens.

The increase in the height of the wall resulted in an increase in the cost of the buildings, but this is approximately offset by the change in the floor construction. The cost of the buildings as constructed, therefore, is probably quite close to that of buildings constructed according to the plans.

The camp buildings housing the sleeping quarters, kitchen and dining room, commissary, and office were of this type and were of the following sizes:

| | Feet. |
|---|---|
| Sleeping quarters | 18 by 54 |
| Kitchen and dining room | 18 by 54 |
| Commissary | 18 by 18 |
| Office | 18 by 18 |

All parts of these buildings were constructed at the county shops at the Bellwood Convict Barracks, in Atlanta. To expedite erection, they were hauled to the camp site unpainted, but before they could be erected the work was halted and the building sections were thoroughly wet by a series of heavy rains. The poorly seasoned lumber absorbed the moisture and swelled so that it was necessary to bore new bolt holes in some places so as to adjust the sections to each other. Subsequently, when the lumber dried, many of the parts contracted, leaving cracks as much as one-fourth inch wide in some places. These were drawn up or filled, and in the fall of 1916 the buildings were in very satisfactory condition. The whole trouble would have been avoided if the sections had been painted inside and out before they were sent to the camp site.

The following is a complete bill of the material and labor entering into the construction of the buildings as described, and the costs given are the actual costs of construction:

*Summary of materials and labor and cost of constructing portable buildings for the Fulton County Experimental Convict Camp.*

Lumber—Longleaf pine, No. 1 common:

| | Sizes. | |
|---|---|---|
| *Pieces.* | Inches. | Feet. |
| 25 | 4 by 18 | 8 |
| 6 | $3\frac{7}{16}$ by $4\frac{7}{16}$ | 18 |
| 11 | 2 by 8 | 18 |
| 162 | 2 by 6 | 18 |
| 15 | 2 by 6 | 16 |
| 9 | 2 by 6 | 12 |
| 315 | 2 by 4 | 18 |
| 63 | 2 by 4 | 16 |
| 42 | 2 by 4 | 12 |
| 10 | 2 by 4 | 10 |
| 50 | 2 by 2 | 18 |
| 1 | 2 by 2 | 12 |
| 69 | 1 by 12 | 16 |
| 34 | 1 by 10 | 16 |
| 4 | 1 by 10 | 12 |
| 30 | 1 by 10 | 10 |
| 14 | 1 by 9 | 18 |
| 305 | 1 by 6 | 18 |
| 830 | 1 by 6 | 12 |
| 46 | 1 by 4 | 18 |
| 4 | 1 by 4 | 16 |
| 22 | 1 by 3 | 18 |
| 5 | 1 by 3 | 12 |
| 165 | 1 by 2 | 18 |
| $13\frac{1}{2}$ | 1 by 2 | 16 |
| 2 | 4 by 5 | 18 |
| 11 | 1 by 1 | 18 |
| 69 | $\frac{1}{2}$ by 3 | 18 |
| 59 | $\frac{1}{2}$ by 2 | 18 |
| 621 | $\frac{7}{8}$ by $3\frac{1}{2}$ T Eb | 18 |
| 136 | $\frac{7}{8}$ by $3\frac{1}{2}$ T Eb | 16 |

Total cost of lumber ........ $493.45

| | | | |
|---|---|---|---|
| Hardware: | | | |
| 7 galvanized-iron ventilators | | $15.75 | |
| | | Inches. | |
| 221 lag screws | | ½ by 3½ | |
| 70 lag screws | | ⅝ by 3½ | |
| 240 lag screws | | ⅝ by 8 | |
| 502 machine bolts | | ½ by 4 | |
| 176 machine bolts | | ½ by 5¼ | |
| 60 machine bolts | | ½ by 5½ | |
| 8 machine bolts | | ½ by 7 | |
| 36 machine bolts | | ½ by 7½ | |
| 12 machine bolts | | ½ by 8 | |
| 432 machine bolts | | ½ by 4¾ | |
| 72 machine bolts | | ⅝ by 3½ | |
| 80 machine bolts | | ½ by 5 | |
| 200 machine bolts | | ½ by 6½ | |
| 64 eyebolts | 1½ eye | ⅝ by 8 | |
| 128 eyebolts | ¾-inch | ⅝ by 6¾ | |
| 12 gross ½-inch wrought washers. | | | |
| 16 dozen ⅝-inch wrought washers. | | | |
| 1,184 ½-inch malleable wing nuts. | | | |
| 456 ⅝-inch malleable wing nuts. | | | |
| 56 pieces 6 by 6 by ⅝-inch angle iron 4 inches long. | | | |
| 700 pieces 4 by 4 by ½-inch angle iron 3½ inches long. | | | |
| 64 pieces ½ by 1½-inch iron 14 inches long. | | | |
| 200 pairs 6-inch tee hinges. | | | |
| 6 deadlocks. | | | |
| 6 door handles. | | | |
| 1 door pull. | | | |
| 35 pieces ⅝-inch round iron 12 feet long. | | | |
| 64 ⅝-inch tie rods, 1 foot 6 inches long, ¾-inch eye. | | | |
| 104 ⅝-inch turnbuckles. | | | |
| 2,100 2-inch No. 16 flathead wood screws. | | | |
| 4 pairs butt hinges 3 by 3 inches. | | | |
| 4 2-inch wire hooks and eyes. | | | |
| 4 double-action hinges. | | | |
| 160 feet 10-inch ridge roll. | | | |
| 32⅔ dozen 1½-inch bright wire hooks and eyes. | | | |
| 100 coach screws. | | | |
| 1 keg 6-penny finishing nails. | | | |
| 1 keg 4-penny common nails. | | | |
| 1 keg 8-penny common nails. | | | |
| 1 keg 10-penny common nails. | | | |
| Total cost of hardware | | | $329.22 |
| Miscellaneous: | | | |
| 42 single sashes 38 inches by 42 inches | | $54.60 | |
| 96 screens with galvanized-wire mesh | | 86.65 | |
| 40 rolls 3-ply ready roofing | | 96.00 | |
| 105 pounds No. 9 flake glue | | 13.65 | |
| Total cost miscellaneous materials | | | 250.90 |

| | | |
|---|---|---|
| Paint: | | |
| 550 pounds white lead | $37.12 | |
| 1 barrel half and half oil | 34.10 | |
| 30 pounds chrome yellow med. in oil | 4.20 | |
| Total cost of paint | | $75.42 |
| Carpenter labor: | | |
| Time of shop foreman | 55.00 | |
| 10.7 days at $3.50 | 37.45 | |
| 88.5 days at $2.50 | 221.25 | |
| 1.5 days at $4 | 6.00 | |
| Total cost of carpenter labor | | 319.70 |
| Blacksmith and machinist labor: | | |
| 4½ days at $2.75 | 12.38 | |
| 5½ days at $2.50 | 13.75 | |
| 4½ days at $2 | 9.00 | |
| Total cost of blacksmith and machinist labor | | 35.13 |
| Painter labor: | | |
| 22 days at $3.50 | 55.00 | |
| 1 month at $40 | 40.00 | |
| Total cost of painter labor | | 95.00 |
| Total cost of buildings | | 1,598.82 |

The above is the cost of constructing the parts and units of the buildings. The cost of assembling them and erecting the buildings at the camp site was as follows:

| | |
|---|---|
| 86½ carpenter days at $2.50 | $216.25 |
| 28 convict days at 77 cents | 21.56 |
| | 237.81 |

If to these costs be added the cost of loading and hauling the sections and parts from the county shops at the Bellwood Convict Barracks, where they were made, to the camp site, which was $76.87, the cost of the buildings erected may be summarized as follows:

| | |
|---|---|
| Cost of materials | $1,148.99 |
| Cost of labor (construction of parts) | 449.83 |
| Cost of loading and hauling | 76.87 |
| Cost of labor (erection) | 237.81 |
| Total cost of buildings erected | 1,913.50 |

Free labor was used in constructing and erecting because all convicts were employed on other work from which they could not be spared. However, it is believed that the work could have been performed satisfactorily by selected convicts at a considerable saving. In view of the fact that the cost of the convict labor was only about 77 cents per working day and the average wage paid to free labor was $2.40, it seems probable that the saving would have amounted to fully one-half the labor cost, or approximately $350, a reduction of about 18 per cent.

### OTHER CAMP STRUCTURES AND FIXTURES.

In addition to the portable buildings the full quarters equipment included two wall tents each 12 by 21 feet; one wall tent 12 by 16 feet, all of 12-ounce duck; and miscellaneous fixtures, such as stovepipe and shelving, and fire extinguishers for the protection of the property. Some of these were purchased after the opening of the camp.

As stated, the stable, harness shed, and blacksmith shop were constructed at the site of rough lumber and galvanized iron. They cost complete $150, but this is regarded as a charge against the work only.

### MOVING PORTABLE BUILDINGS.

The structures were designed to combine strength, durability, convenience, sightliness, and portability, and to admit abundant light and air. It was hoped that they would meet satisfactorily the requirements of camps which are moved from one site to another at intervals of from 6 to 12 months, taking the place of the tent, the cheap shack, and the convict cage, none of which is entirely satisfactory. Therefore, the economy and convenience with which they were razed, transported to a new site, and reerected were among the most interesting developments of the experiment.

The original plan was to move the camp to a new site immediately upon completion of the grading on the Powers Ferry Road. Consequently, early in July a site was prepared on Hemphill Avenue, 3¾ miles from the first site. A road was cleared as an approach from the public road, a cesspool was excavated, posts were cut and set to line and elevation to receive the sills of the buildings, and a well was begun and almost completed when the commissioners decided to surface the Powers Ferry Road with top soil before leaving the first site. Shortly after this the convicts were transferred to the fairgrounds, and the top soiling was not completed until November 11. Moving of the quarters was begun on November 15. At that time the camp population was half depleted, and the quarters intended for the accommodation of 40 men were moved with a force of 23. This shortage of labor naturally resulted in a considerable increase in the time required to complete the moving. The facts that the working-day at that season was only eight hours long and that the first cold weather of the year was experienced during the week also served to prolong the time required, and the buildings were not completely erected at the new site until November 22, one week from the time the transfer was begun. However, an analysis of the costs of moving given in Table 1 shows the actual labor expended on the work was equivalent to only about 3⅓ days of work with the full working force of 37 men.

Some damage and loss is inevitable in moving buildings of any sort a distance of 3¾ miles. That resulting from the transfer of these buildings was very slight. The total damage consisted of one broken tie rod, one broken rafter, one broken collar beam, and four broken window lights. The loss amounted to 190 board feet of lumber, 6 gallons of roofing cement, 12 squares of 2-ply ready roofing, and 10 pounds of roofing nails, the last three items resulting from the necessary reconstruction of the roofing laps. The tie rod, rafter, and collar beam were repaired at the camp, and the cost is included in the labor cost. The other items are added to the labor cost in Table 1, which shows that the total expense of moving the four buildings was $191.70.

TABLE 1.—*Cost of moving portable buildings at the Fulton County, Ga., Experimental Convict Camp.*

| | | |
|---|---|---|
| Setting foundation posts: | | |
| 2 carpenter days, at $2.26 | $4.52 | |
| 13 convict days, at 77 cents | 10.01 | |
| | | $14.53 |
| Razing buildings: | | |
| 2½ foreman days, at $1.90 | 4.75 | |
| 2 foreman days, at $2.90 | 5.80 | |
| 36½ convict days, at 77 cents | 28.10 | |
| | | 38.65 |
| Loading and hauling buildings: | | |
| 17½ convict days, at 77 cents | 13.48 | |
| 14½ team days, at $1.91 | 27.70 | |
| | | 41.18 |
| Erecting buildings: | | |
| 2 foreman days, at $1.90 | 3.80 | |
| 1 foreman day at $2.90 | 2.90 | |
| 7 carpenter days, at $2.50 | 17.50 | |
| 57 convict days, at 77 cents | 43.89 | |
| | | 68.09 |
| Damage and loss: | | |
| Replacing 4 window lights | 1.00 | |
| 190 feet b. m. lumber, at $20 per M | 3.80 | |
| 6 gallons roofing cement, at 65 cents | 3.90 | |
| 12 squares ready roofing, at $1.55 | 18.60 | |
| 10 pounds roofing nails, at 6 cents | .60 | |
| | | 27.90 |
| Total cost of moving buildings | | 190.35 |

## OTHER COSTS OF MOVING CAMP.

The cost of $190.35, given above, represents the expense of moving the portable buildings only. The complete costs of moving the entire camp a distance of 3¾ miles, including 1 mile over a bad road, are given in Table 2.

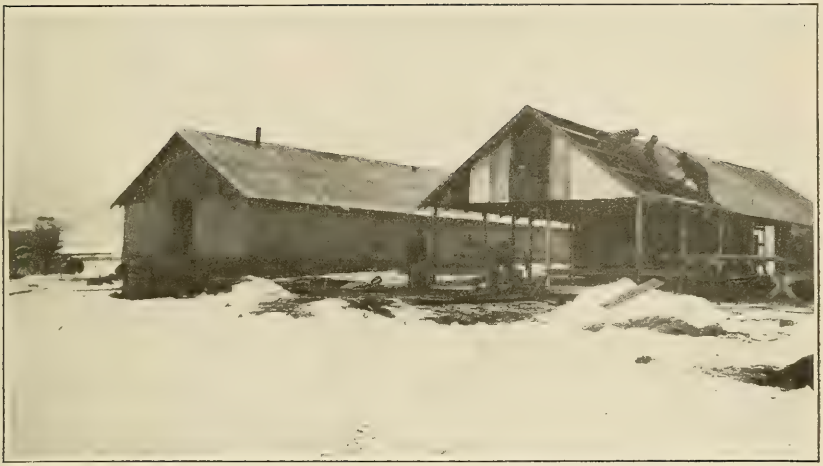

FIG. 1.—QUARTERS IN THE VIRGINIA CAMP. NO PROVISION FOR ADMISSION OF LIGHT OR AIR.

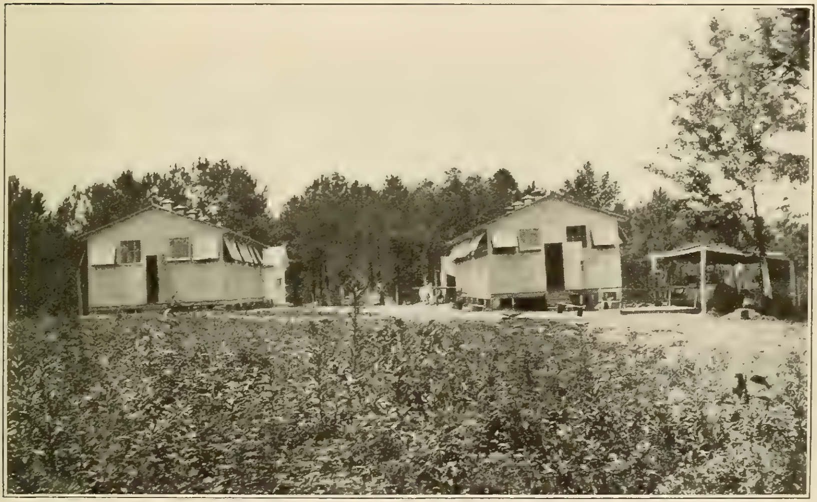

FIG. 2.—PORTABLE QUARTERS OF THE GEORGIA CAMP. DESIGNED TO ADMIT ABUNDANT LIGHT AND AIR.

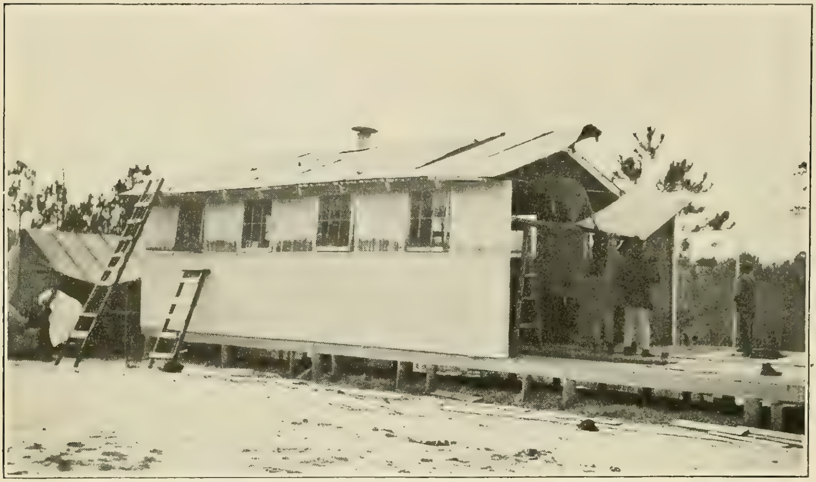

FIG. 1.—TEARING DOWN BUILDING BEFORE MOVING EXPERIMENTAL CAMP.

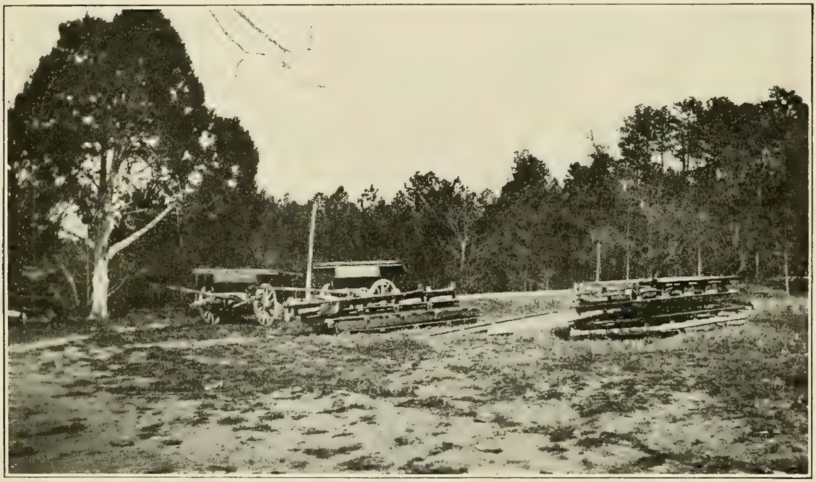

FIG. 2.—WAGON BEDS USED FOR MOVING CAMP AND SECTIONS OF BUILDINGS.

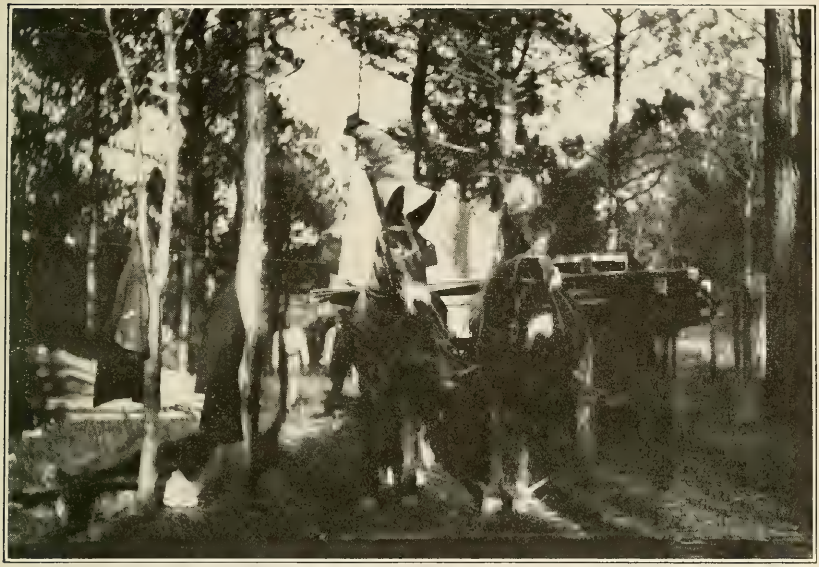

FIG. 1.—MOVING EXPERIMENTAL CAMP.

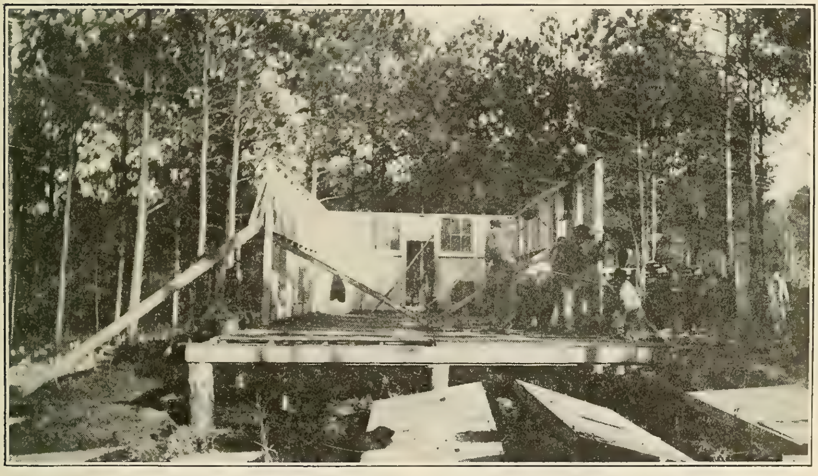

FIG. 2.—ERECTING BUILDINGS AFTER MOVING EXPERIMENTAL CAMP.

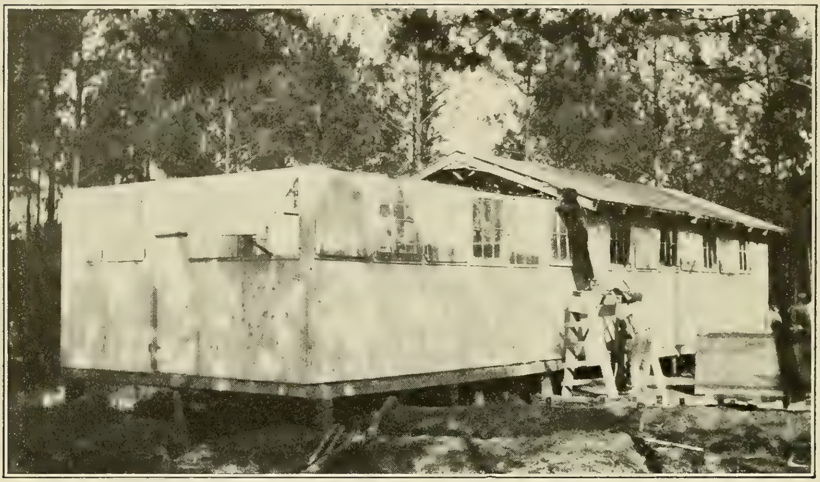

FIG. 1.—PLACING ROOF ON BUILDINGS AFTER MOVING EXPERIMENTAL CAMP.

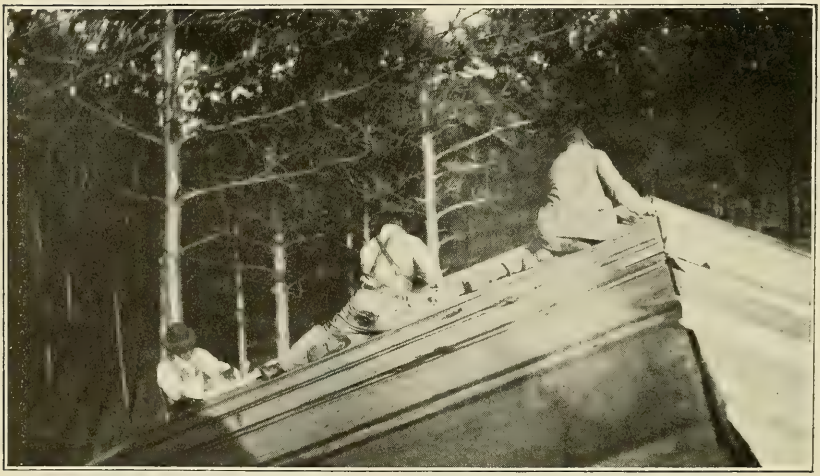

FIG. 2.—PUTTING ON ROOF STRIPS AFTER MOVING EXPERIMENTAL CAMP.

TABLE 2.—*Complete cost of moving camp, Fulton County, Ga., Experimental Convict Camp.*

| | |
|---|---|
| Moving portable buildings | $190.35 |
| Moving other buildings and tents | 48.03 |
| Preparing new well | 134.11 |
| Excavating cesspool | 12.08 |
| Clearing site, and miscellaneous | 39.03 |
| Plumbing | 25.00 |
| Fencing | 7.12 |
| Clearing roadway to camp | 13.37 |
| Total cost of moving camp | 469.09 |

With the purpose of discovering how these structures compare in portability with structures of other types an engineer was assigned to observe the moving of a camp of 48 convicts at Washington, Va. The quarters in this camp were not of the so-called "portable" type, but were designed to be transferable readily from one site to another. As shown in Plate I, figures 1 and 2, they consisted simply of a galvanized-metal roof supported by posts set into the ground, the sides being inclosed only by curtains of cotton duck. It is evident that they are not as substantial nor do they afford as much shelter as the portable buildings used in the experimental camp. The comparative cost data on the moving of the two sets of structures, given in Table 3, therefore is of considerable interest, as it shows that in expenditure of labor the moving of the Virginia buildings was much more costly than the portable buildings, though the actual cash expenditure in each case was about the same on account of the lower wages paid to guards and foremen and the lower convict-maintenance cost in Virginia.

In each case the camp was moved approximately 3¾ miles, including 1 mile over a bad road. Weather conditions favored the Atlanta operations to the extent that the transfer there was made in November when the working day contained 8 hours, and only one day of the seven over which the operations were extended was disagreeably cold, whereas the Virginia camp was moved in December when the length of the working day was only 7 hours, the temperature uncomfortably low, and snow covered the ground throughout the week occupied by the moving. As the Virginia data cover the cost of moving only the camp buildings, the similar items on the cost of moving the Atlanta camp have been selected for comparison.

TABLE 3.—*Comparison of cost of moving portable buildings and Virginia camp buildings.*

| Atlanta camp. | | | | Virginia camp. | | | |
|---|---|---|---|---|---|---|---|
| Operation. | Actual cost. | | Convict labor. | Operation. | Actual cost. | | Convict labor. |
| Setting foundation posts: | | | *Days.* | Setting posts: | | | *Days.* |
| 2 carpenter days, at $2.26. | $4.52 | | | 18½ convict days, at 60 cents.[1] | | $11.10 | 18.5 |
| 13 convict days, at 77 cents. | 10.01 | $14.53 | 13.0 | | | | |
| Razing buildings: | | | | Razing buildings: | | | |
| 2½ foreman days, at $1.90. | 4.75 | | | 84 convict days, at 60 cents. | | 50.40 | 84.0 |
| 2 foreman days, at $2.90. | 5.80 | | | | | | |
| 36½ convict days, at 77 cents. | 28.10 | 38.65 | 36.5 | | | | |
| Loading and hauling buildings: | | | | Loading and hauling buildings: | | | |
| 17½ convict days, at 77 cents. | 13.48 | | | 17 convict days, at 60 cents. | $10.20 | | |
| 14½ team days, at $1.91 | 27.70 | 41.18 | 17.5 | 17 team days, at $1.91 | 32.47 | 42.67 | 17.0 |
| Erecting buildings: | | | | Erecting buildings: | | | |
| 2 foreman days, at $1.90 | 3.80 | | | 103 convict days, at 60 cents. | | 61.80 | 103.0 |
| 1 foreman day, at $2.90. | 2.90 | | | | | | |
| 7 carpenter days, at $2.50. | 17.50 | | | | | | |
| 57 convict days, at 77 cents. | 43.89 | 68.09 | 57.0 | | | | |
| Moving stable, barn, and officers' tents: | | | | Moving stable: | | | |
| 1 foreman day, at $2.25 | 2.25 | | | 7 team days, at $1.91 | 13.37 | | |
| 2 foreman days, $1.90 | 3.80 | | | 60 convict days, at 60 cents. | 36.00 | 49.37 | 60.0 |
| 1 blacksmith day, at $2.25 | 2.25 | | | | | | |
| 2 team days, at $1.91 | 3.82 | | | | | | |
| 46 convict days, at 77 cents. | 35.42 | 47.54 | 46.0 | | | | |
| Damage and loss: | | | | Damage and loss: | | | |
| Replacing 4 window lights | 1.00 | | | 1,500 feet b. m. lumber, at $12.50 per M. | | 18.75 | ........ |
| 190 feet b. m. lumber, at $20 per M. | 3.80 | | | | | | |
| 6 gallons roofing cement, at 65 cents. | 3.90 | | | | | | |
| 12 squares ready roofing, at $1.55. | 18.60 | | | | | | |
| 10 pounds roofing nails, at 6 cents. | .60 | 27.90 | ........ | | | | |
| Total | | 237.89 | 170.0 | Total | | 234.09 | 282.5 |

[1] Salaries of guards and foremen included in the maintenance cost of prisoners.

## DEPRECIATION OF PORTABLE BUILDINGS.

It is impossible to forecast at this time what will be the life of the buildings. On July 10, 6 months after they were put into service, there was no noticeable depreciation. After their transfer to the new site, when they were more than 10 months old, the actual observable damage and loss amounted to less than 1½ per cent of their value; it may be said safely that the total depreciation during the first year amounted to no more than 5 per cent. It is to be expected that this rate will increase each year during the economic life of the buildings, but what this rate will be can not be predicted. From present indications it seems entirely possible that their life may be as long as 8 years, but this figure probably is too great to use as a basis for estimating the economy of the buildings. It has been assumed for this purpose that the rate of depreciation will increase each year by an increment of 5 per cent, beginning with 5 per cent the first year. According to this assumption, which certainly is sufficiently severe, the life of the buildings will be almost 6 years; but to be still more conservative, the fraction has been dropped and the economic life has been taken at 5 years for all purposes of cost computation.

### COST OF QUARTERS ON ANNUAL BASIS.

The total cost of all camp quarters up to July 10, the date of the first inventory, is given in Table 4.

TABLE 4.—*Total cost of all quarters at Fulton County, Ga., Experimental Convict Camp, from January 10 to July 10, 1916.*

| | |
|---|---|
| Portable buildings erected | $1,913.50 |
| 2 wall tents, 12 by 21 feet, walls 6 feet | 90.84 |
| 1 wall tent, 12 by 16 feet, walls 6 feet, with fly | 41.25 |
| Miscellaneous fixtures, appliances, and additions | 193.96 |
| Total cost to July 10 | 2,239.55 |

In determining the per-capita per-day cost of the quarters it has been considered that the entire cost of erecting the quarters and loading and hauling them should be charged off in the period of 311 days during which the camp occupied its first site, and a proportional amount has been allowed for the 183 days up to July 10. With this procedure in mind it is believed that the per-capita costs per day given in Table 5 will require no further explanation.

TABLE 5.—*Cost of quarters per capita per calendar day for period January 10 to July 10, 1916, Fulton County, Ga., Experimental Convict Camp.*

| | |
|---|---|
| Depreciation of portable buildings at 20 per cent per year, original value $1,598.82 | $159.88 |
| Proportional cost of loading and hauling and erection $=\frac{183}{311}$ of 314.68 | 185.17 |
| Depreciation of 12 by 16 foot tent and fly at 25 per cent per year, original value, $41.25 | 5.15 |
| Depreciation of two tents, each 12 by 21 feet, at 50 per cent per year, original value, $90.84 | 22.71 |
| Interest on original investment of $2,045.90, at 6 per cent per year | 61.38 |
| Depreciation of miscellaneous fixtures, appliances, and additions, estimated | 12.42 |
| Cost of quarters from Jan. 10 to July 10 | 446.71 |
| Total number of convict calendar days from Jan. 10 to July 10, 1916 | 7,174 |
| Cost of quarters per convict per calendar day | $0.0623 |

### THE WATER SUPPLY.

The water supply at both sites was obtained from wells dug by the convicts. Both were dug through a micaceous clay soil for their entire depth. That at the first site was 51 feet deep by 6½ feet in diameter and cost $39.90 to excavate. The second well was 49½ feet deep by 7 feet in diameter and cost $43.31 for excavating, $76.46 for a galvanized-iron casing 16 feet long, including the cost of hauling and placing, and $14.34 for a concrete curbing, or $134.11 in all.

The flow of the well at the first site was approximately 1,200 gallons in 24 hours. The consumption of water for bathing, according to meter measurement, was 15 gallons per man per day. The consumption for other purposes, estimated, also was 15 gallons. The flow, as will be seen from these figures, was approximately equal to the demand on the bathing days. That there was actually no reserve flow was shown by the fact that when, for a short period in the spring, the stock was watered from the well instead of from the neighboring creek from which they customarily were supplied, the draft was much too heavy for the supply.

An analysis of the water made by the health department of Atlanta about a month after the opening of the camp showed that the water contained 46 bacteria per cubic centimeter and no colon bacilli in 10 cubic centimeters, indicating that the sanitary quality of the water was satisfactory.

The water was piped from the well (Pl. V, fig. 1) to the sleeping quarters, to supply the water-closets and wash trough, to the showers in the bath tent (Pl. V, fig. 2), to the kitchen, and to three outside faucets. It was forced from the well to the faucets by air pressure operating in a pneumatic pump installed in the well. The air was supplied to the pump from an air tank of 100 cubic feet capacity, in which it was stored by means of an air compressor driven by a 2¾-horsepower gasoline engine. The cost of the water-supply equipment is given in Table 6, below:

TABLE 6.—*Cost of water-supply equipment.*

| | |
|---|---|
| 1 2¾-horsepower gasoline engine | $62.75 |
| 18 feet 3-inch belting | 17.28 |
| Second-hand outfit consisting of— | |
| 1 pneumatic pump | 300.00 |
| 1 air tank, 100 cubic feet capacity | |
| 1 air compressor | |
| Pressure gages and fittings | |
| (New value, $360.) | |
| 1 20 by 40 inch sink | 5.10 |
| 1 2-inch standard P trap | .45 |
| 2 2-inch standard ¼ bend | .70 |
| 1 2-inch standard reducing Y, 2 by 4 by 4 inches | .87 |
| 20 2-inch standard S. H. pipe | 1.60 |
| 100 feet 1½-inch black pipe | 7.87 |
| 70 feet 1-inch black pipe | 3.40 |
| 50 feet ¾-inch galvanized pipe | 2.51 |
| 1 pair sink brackets | .30 |
| 5 1-inch galvanized standard ells | .56 |
| 6 ¾-inch galvanized standard ells | .48 |
| 12 ¾-inch galvanized nipples | .43 |
| 8 ⅜-inch galvanized jam nipples | .24 |
| 1 1-inch globe valve | 1.00 |
| 6 1½-inch black ells | .54 |

| | |
|---|---|
| 6 1½-inch black tees | $0.60 |
| 6 1½ by ¾ inch black tees | .66 |
| 2 1¼ by ¾ inch black reducing ells | .20 |
| 2 1 by ¾ inch black reducing ells | .18 |
| 4 1-inch black ells | .30 |
| 2 1½-inch black G. J. unions | .84 |
| 2 1-inch black G. J. unions | .60 |
| 6 ¾-inch black G. J. unions | 1.08 |
| 6 ¾-inch black ells | .17 |
| 6 ¾-inch hose bibs | 4.50 |
| Second-hand piping: | |
| 30 feet ¾-inch galvanized pipe | 11.65 |
| 45 feet ½-inch galvanized pipe | |
| 65 feet 1-inch galvanized pipe | |
| 2 hot-water heaters | 17.00 |
| 1 40-gallon hot-water tank | 8.75 |
| Total cost water-supply equipment | 452.61 |

Once each day, except bathing days, the engine was operated from a half hour to one hour to charge the air tank with air at 100 pounds pressure. On bathing days it was necessary to recharge the tank immediately before the bathing began. With the tank charged a supply of water was always available at any of the faucets, as the opening of a faucet automatically set the pump to work.

Four shower fixtures were provided in the bath tent, and water was heated for bathing by two heaters coupled in tandem, having a combined water-heating surface of 880 square inches, and a grate area of 127 square inches. A 40-gallon tank was installed for the storage of hot water.

Table 7 shows the results of a test of the efficiency of the hot-water system.

TABLE 7.—*Results of a test of the hot-water system at the Fulton County, Ga., Experimental Convict Camp.*

| | |
|---|---|
| Heater dimensions: | |
| Grate area | 127 square inches. |
| Heating area | 880 square inches. |
| Temperatures: | |
| Feed water | 57° F. |
| Bath water | 105° F. |
| Air in tent | 94° F. |
| Air outdoors | 46° F. |
| Time: | |
| Fires started | 3.30 p. m. |
| Bathing started | 5.00 p. m. |
| Bathing finished | 5.30 p. m. |
| Fuel consumption: | |
| Wood | 5 pounds. |
| Coal | 32 pounds. |
| Water consumption (metered), 80 cubic feet | 600 gallons. |
| Hot water remaining in tank at 5.30 p. m. | 20 gallons. |
| Number of inmates bathed | 40 |

The water system at the first site was used for a period of 311 days. Charging off the entire cost of the well and the labor of installation in that time, and computing the cost of these two items in proportion to time the total and per capita costs of the water used during the first six months, or 183 days, of operation are given in Table 8.

TABLE 8.—*Total and per capita cost of water supply from January 10 to July 10, 1916, Fulton County, Ga., Experimental Convict Camp.*

| | |
|---|---|
| Proportion of cost of well | $23.48 |
| Depreciation of gasoline engine and belt | 8.03 |
| Depreciation of air pump and outfit | 25.00 |
| Depreciation of piping and fixtures | 4.93 |
| Lubricating oil, 12 gallons, at 40 cents | 4.80 |
| Cup grease, 10 pounds | .87 |
| Gasoline, 210 gallons, at 21 cents | 44.10 |
| Proportion of cost of installation | 21.64 |
| Total cost for six months | 122.85 |
| Total number of convict calendar days from Jan. 10 to July 10, 1916 | 7,174 |
| Cost of water supply per convict per calendar day | $0.0171 |

## SEWAGE DISPOSAL.

The plan of sewage disposal recommended by the Federal bureaus was that of sanitary privies for the temporary reception of the wastes, and ultimate shallow burial. Comparatively few convict camps are able to dispose of their sewage by means other than privies; but a truly sanitary privy is found rarely, and the method of its operation is not generally understood. The methods employed in the temporary camps and those somewhat removed from the larger centers of population usually are particularly primitive and the sanitary conditions especially bad. It was hoped the demonstration at the experimental camp would be of most service to these classes of camps. But on account of past disagreeable experiences with poorly kept privies the county commissioners had decided to use flush toilets in all county camps, and deferring to their objection to the recommended method it was agreed to install flush toilets and a cesspool.

The cesspool was excavated at a point 100 yards from the main camp buildings and well, at an elevation 25 feet below them and on a slope leading away from the camp. It was covered with boards over which several inches of earth was spread. As the location was sufficiently removed from dwellings and potable water supplies the pit was left unlined so that its contents might seep into the ground. Its dimensions were 12 feet in width, 20 feet in length, and 10 feet in depth; and into it were piped the wastes of the kitchen, lavatory, shower bath, and water-closets, amounting to fully 600 gallons per day. This large discharge was cared for successfully until the 1st day of June, when the pit was filled to overflowing. From that time until the convicts were transferred to the fair grounds there was a slight overflow every day. As the effluent flowed away from the camp and the conditions were such that it endangered no water supply, as, moreover, the odor was scarcely perceptible, it was believed unnecessary to transfer to another pit. While the men were at the fair grounds the fluids disappeared completely and the same pit was used until the middle of November. The cost of the pit, including the laying of 300 feet of sewer tile, was $22.50.

Three rim-flushed hoppers were placed in a corner of the sleeping quarters for the use of the men, and one was provided for the officers in a closet adjacent to the quarters building. The cost of these hoppers and the necessary piping was $62.83. The cost of the system for the first 6 months of operation and the per capita cost per day are shown in Table 9. In computing these costs the entire cost of the cesspool and the labor of installation have been charged off in 311 days, the time the first site was occupied. The proportional costs for the first 183 days were figured at the rate thus indicated.

TABLE 9.—*Total per capita cost of sewage disposal from January 10 to July 10, 1916, Fulton County, Ga., Experimental Convict Camp.*

| | |
|---|---|
| Proportional cost of cesspool | $13.06 |
| Depreciation of hoppers and piping | 20.93 |
| Proportion of cost of installation | 7.22 |
| Total cost for six months | 41.21 |
| Total number of convict calendar days from Jan. 10 to July 10, 1916 | 7,174 |
| Cost of sewage disposal per calendar day | $0.0057 |

## GARBAGE DISPOSAL.

Prior to the opening of the experimental camp it was customary in the other camps of the county to collect the garbage in the kitchen in open pails and to dump it later into uncovered receptacles, usually of wood, at a short distance from the buildings. When a sufficient amount had accumulated in these it was fed to hogs, of which every camp had a number. Strong recommendations for a change in these methods were made by the sanitary officer representing the Public Health Service, but during the first month of operation the same methods were employed in the cooperative camp. About the middle of February covered metal receptacles were substituted for the open ones, and an incinerator of the barrel type [1] made of field stone and clay was constructed for the destruction of the solid wastes. However, though the conditions around the pigpen were most offensive at times, and though the representatives of the Federal bureaus did all in their power to have the hogs removed, their efforts were not successful until April 21, when the nuisance was abolished largely because the table waste had been so reduced that there was no longer enough to keep the hogs alive. From that date until the termination of the cooperative arrangement the waste was disposed of partly by incineration and partly by trading with a neighboring farmer for buttermilk and milk. When representatives of the Office of Public Roads returned to the county to observe the moving of the camp it was found that the hogs had been installed again, this time, however, in a pen somewhat more removed from the quarters than the first one. The results of this phase of the experiment, therefore, can not be considered as fully successful.

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[1] For description, see Bulletin No. 414, U. S. Department of Agriculture, p. 103.

The incinerator (Plate VI, fig. 2) was constructed by the representative of the Public Health Service, assisted by the blacksmith's helper, a convict, at a time when there was nothing else to do. The convict's time had been charged to other work and no charge has been entered for the incinerator. As no other phase of the garbage disposal involved any tangible expense, this item has not been considered in determining the cost of the camp.

## CLOTHING.

The clothing used was of the same character as that provided in the other camps of the county, and it was supplied in approximately the same amount. The accuracy of the records of the cost of this item of maintenance was impaired somewhat by the fact that the clothes sent to the laundry at the Bellwood Barracks were not always returned. In a number of instances the condition of the garments which were returned was far below that of those sent. In other cases it is possible that the exchange was advantageous. No estimate can be made of the loss or gain due to this cause, but it is considered that the net result probably was a loss to the experimental camp. The records and inventories made at the camp, however, were made with judgment and care, and the results are given in Table 10, which also includes a statement of the per capita costs.

TABLE 10.—*Inventory and per capita cost of clothing, Fulton County, Ga., Experimental Convict Camp (1916).*

| Item. | | Unit cost. | Value of items purchased or acquired first 6 months. | Inventory value July 10, 1916. | Value used. | Number of convict calendar days. | Cost per convict per calendar day. |
|---|---|---|---|---|---|---|---|
| Pants | dozen | $11.25 | $154.25 | $108.00 | $46.25 | 7,174 | $0.0064 |
| Coats | do | 18.00 | 37.00 | 33.00 | 4.00 | 7,174 | .0006 |
| Shoes | pairs | 2.00 | 120.00 | 52.00 | 68.00 | 7,174 | .0096 |
| Undershirts | dozen | 2.15<br>1.08 | 14.88 | 9.63 | 5.25 | 7,174 | .0007 |
| Drawers | do | 4.12<br>1.08 | 24.62 | 1.22 | 23.40 | 7,174 | .0032 |
| Sole leather | pounds | .43 | 9.89 | 3.01 | 6.88 | 7,174 | .0009 |
| Socks | pairs | .07 | 3.68 | .70 | 2.98 | 7,174 | .0004 |
| Night shirts | dozen | 8.50<br>3.50 | 50.38 | 4.09 | 46.29 | 7,174 | .0064 |
| Shirts | do | 7.25<br>3.50 | 107.67 | 28.49 | 79.18 | 7,174 | .0110 |
| Oil coats | do | 25.00 | 12.50 | 6.25 | 6.25 | 7,174 | .0009 |
| Caps | do | 3.00 | 5.50 | .......... | 5.50 | 7,174 | .0008 |
| Thread | do | .50 | 1.13 | .......... | 1.13 | 7,174 | .0002 |
| Towels | do | .50 | .80 | .......... | .80 | 7,174 | .0001 |
| Total | | .......... | 542.30 | 246.39 | 295.91 | 7,174 | .0412 |

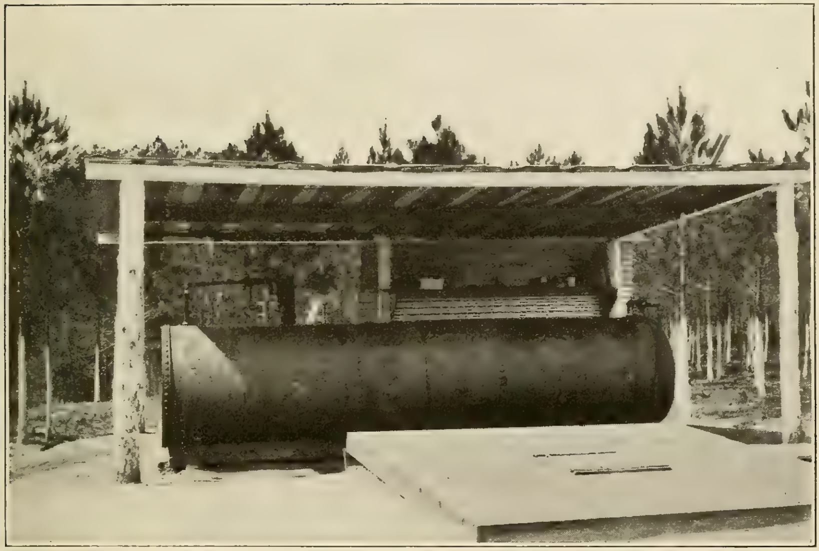

FIG. 1.—AIR TANK AND WELL, EXPERIMENTAL CAMP.

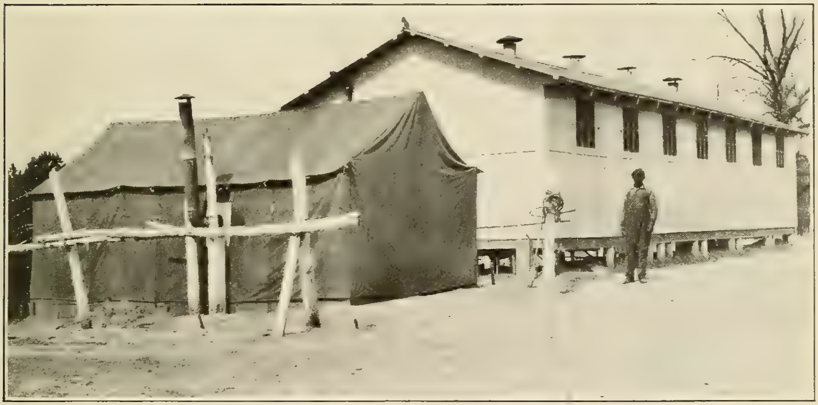

FIG. 2.—BATH TENT IN REAR OF QUARTERS, EXPERIMENTAL CAMP.

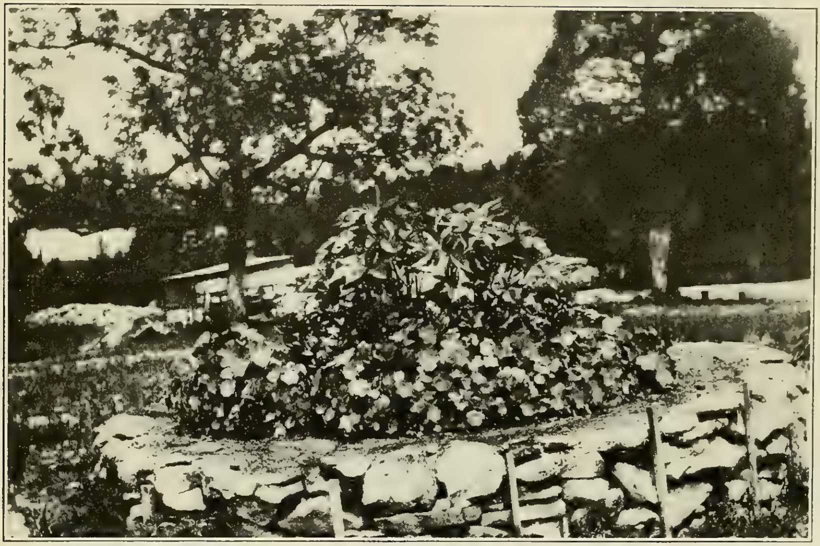

FIG. 1.—FLOWER BED, EXPERIMENTAL CAMP.

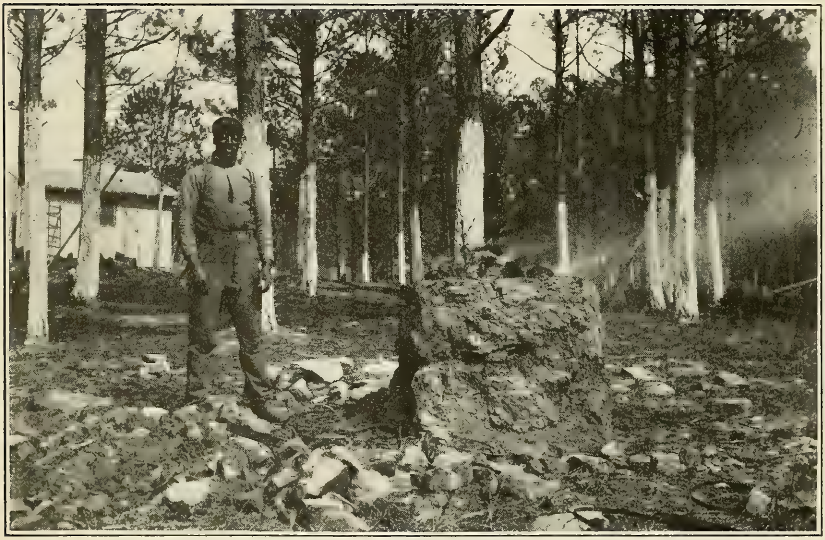

FIG. 2.—INCINERATOR, EXPERIMENTAL CAMP.

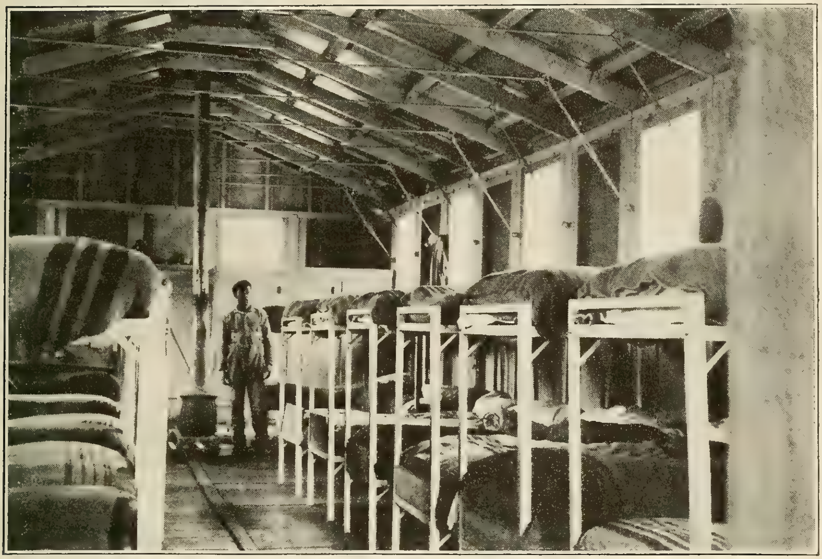

FIG. 1.—INTERIOR OF QUARTERS, EXPERIMENTAL CAMP, SHOWING DOUBLE-DECK IRON BEDS.

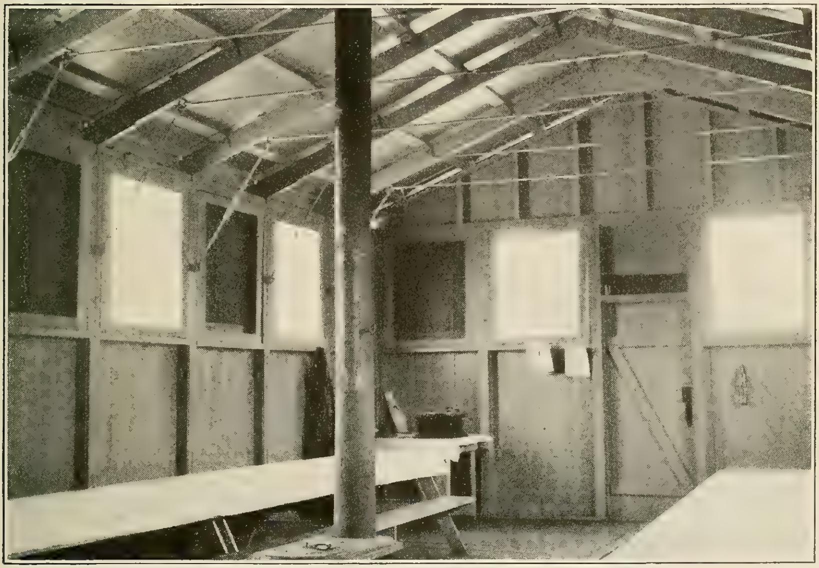

FIG. 2.—INTERIOR OF DINING ROOM, EXPERIMENTAL CAMP.

### LAUNDRY.

All laundering was done at the Bellwood Barracks, where a laundry was provided to which was sent clothing from all the county camps. Once each week the laundry truck called for and delivered the camp wash. The method was a good one from a sanitary standpoint, but it is doubtful whether it resulted in true economy; and, as has been stated, its effect on the cost records kept at the experimental camp was to render their accuracy somewhat doubtful.

The value of the laundry buildings and equipment was estimated at $3,609.76. The plant was operated by a laundry engineer whose salary was $60 per month, assisted by four convicts at $0.77 per working day. The expense for soap during the first six months' operation of the experimental camp was $72; for oils and grease, $36 and for coal, $397.44. The value of the laundry truck was $900, and depreciation was estimated at the rate of 33.33 per cent per year for the period from January 10 to July 10. The salary of the chauffeur was $60 per month; and gasoline, oils, and repairs for the machine amounted to $180 for the period of six months. The total costs of the laundry and the costs per convict per day are summarized in Table 11.

TABLE 11.—*Total and per capita costs of laundry, Fulton County, Ga., Experimental Convict Camp (1916).*

| | Cost for 6 months, all camps. |
|---|---|
| Interest on buildings and equipment, value $3,609.76 at 6 per cent per year | $108. 29 |
| Depreciation of buildings and equipment estimated at 10 per cent per year | 180. 49 |
| Interest on laundry truck, value $900, at 6 per cent per year | 27. 00 |
| Depreciation of laundry truck estimated at 33.33 per cent per year | 150. 00 |
| Chauffeur's salary | 360. 00 |
| Gasoline, oil, grease, and repairs to truck | 180. 00 |
| Laundry engineer's salary | 360. 00 |
| Soap and laundry material | 72. 00 |
| Oil, waste, etc., for laundry machinery | 36. 00 |
| Coal, 138 tons at $2. 88 | 397. 44 |
| Convict labor | 450. 00 |
| Total cost of laundry for all camps, six months | 2, 321. 22 |
| Ratio of population of experimental camp to total county population | . 07 |
| Total cost of laundry for experimental camp | $162. 49 |
| Total number of convict calendar days from Jan. 10 to July 10, 1916 | 7, 174 |
| Cost of laundry per convict per calendar day | $0. 0226 |

### FURNITURE AND EQUIPMENT.

The beds and mess tables (see Pl. VII and detached appendix plate) used in the camp represent a distinct advance in point of convenience, suitability, and sanitary qualities over those in use in the large majority of camps in the State and county.

*Beds.*—The beds were double-decked cots constructed of steel angles, and were provided with a wire-link fabric attached to the frame by means of helical wire springs to support the mattress. Upper and lower cots were 6½ feet in length and 2½ feet in width. The lower frame was 18 inches from the floor and the upper one was 2½ feet above the lower. The metal frames were coated with aluminum paint and the wire fabric was galvanized to prevent rusting. Each double-deck cot cost $5.03 f. o. b. Atlanta.

Ticks filled with straw served for mattresses with very satisfactory results in point of cleanliness and comfort. It is believed that mattresses of this kind are more suitable for convict camps than the more espensive hair and cotton mattresses. The rest of the sleeping equipment consisted of an allowance of one straw-filled pillow tick, two pillow slips, four sheets of unbleached muslin, and three or four blankets for each convict.

*Mess tables.*—The mess tables with combined benches were constructed by the county's carpenters at the Bellwood Barracks according to plans supplied by the Office of Public Roads and Rural Engineering, and published in Bulletin No. 414 of the United States Department of Agriculture. (See detached appendix plate.) Six of these tables were constructed for the camp and, in the interest of neatness, white oil cloth was provided as a covering. The total cost of labor and materials for the tables was $20.15 and for the oil cloth, $5.85. A complete list of the furniture and equipment purchased from January 10 to July 10 is given in Table 12, which also shows the unit cost and estimated depreciation of each article.

TABLE 12.—*List of furniture and equipment purchased from January 10 to July 10, 1916, Fulton County, Ga., Experimental Convict Camp.*

| | Depreciation. |
|---|---|
| 18 wall lamps at 75 cents each | $0.72 |
| 6 lanterns at $4 per dozen | .70 |
| 7 lanterns at $4.50 per dozen | .75 |
| 2 small glass lamps at 20 cents each | .15 |
| 20 wall-lamp globes at 75 cents per dozen | .45 |
| 24 lantern globes at 50 cents per dozen | .50 |
| 5 lamp chimneys at 50 cents per dozen | .21 |
| 17 10-quart galvanized buckets at $3.90 per dozen | 4.25 |
| 4 2½ by 6 foot single cots at $6.50 each | 2.00 |
| 23 double-deck cots at $5.03 each | 25.15 |
| 6 cotton mattresses at $3.75 each | 2.00 |
| 240 bed sheets at 27 cents each | 9.04 |
| 61 pillow slips at 17¼ cents each | 2.15 |
| 214 blankets at 87½ cents each | 80.72 |
| 50 blankets at 95 cents each | 23.95 |
| 74 pillow ticks at 18 cents each | 9.65 |
| 50 mattress ticks at 72 cents each | 5.04 |
| 1,000 pounds straw for ticks at $11 per ton | 5.50 |
| 6 combined mess tables and benches at $3.36 each | 1.95 |
| 3 rolls oil cloth (for tables) at $1.95 each | 4.39 |
| 10 armchairs at $1 each | 2.00 |

| | Depreciation. |
|---|---|
| 1 flat-top desk at $10 | $0.25 |
| 6 wood stoves at $8.75 each | 13.13 |
| 6 cuspidors at $7 per dozen | .50 |
| 1 crate toilet paper at $6.25 | 3.93 |
| 5 gallons disinfectant at 45 cents per gallon | 2.25 |
| 1 platform scale at $19 | .50 |
| 1 butcher's spring scale at $3.50 | .25 |
| 8 brooms at $4.50 per dozen | 1.20 |
| 6 brooms at $3.60 per dozen | 1.34 |
| 100 feet ½-inch garden hose at $8.50 | 1.25 |
| 60 pounds screen wire (for fly traps) at 2½ cents per pound | 1.50 |
| 4 packages tacks (for fly traps) at 2½ cents per package | .10 |
| 25 sheets fly paper at 2 cents each | .50 |
| 1 garbage can at $1.50 | .38 |
| 1 garbage can at $3.30 | .82 |
| Total depreciation in 6 months | 209.17 |

As the total number of convict calendar days from January 10 to July 10 was 7,174, the cost of furniture and equipment per convict per calendar day was $0.0291.

### KITCHEN AND MESS EQUIPMENT.

Table 13 gives a complete list of all kitchen and mess equipment used in the camp, the general character of the equipment being indicated by the unit costs which are attached to each article. A statement of the depreciation of each article during the period from January 10 to July 10, 1916, also is given:

TABLE 13.—*List of kitchen and mess equipment purchased from January 10 to July 10, 1916, Fulton County, Ga., Experimental Convict Camp.*

| | Depreciation. |
|---|---|
| 22 china dinner plates at $1,50 per dozen | $0.77 |
| 11 china cups at 75 cents per dozen | .05 |
| 10 china saucers at 75 cents per dozen | |
| 15 tin plates at 21 cents per dozen | .26 |
| 28 knives at 35 cents per dozen | .58 |
| 35 forks at 35 cents per dozen | .76 |
| 28 teaspoons at 10 cents per dozen | .16 |
| 22 tablespoons at 20 cents per dozen | .23 |
| 35 enameled plates at $1.50 per dozen | |
| 49 pint tin cups at 10 cents per dozen | .41 |
| 21 two-quart dinner buckets at 54 cents per dozen | .20 |
| 15 four-quart dinner buckets at $2.20 per dozen | 1.50 |
| 3 three-quart dinner buckets at 80 cents per dozen | .10 |
| 6 sirup pitchers at 20 cents each | |
| 20 dippers at 5 cents each | .62 |
| 2 three-gallon tin coffee pots at $1.20 | 1.45 |
| 1 two-gallon enamel coffee pot at 95 cents | .37 |
| 4 five-gallon milk cans at $1.90 | .55 |
| 1 stock pot (4 gallons) at $2.50 | .55 |
| 1 stock pot (5 gallons) at $5 | 1.25 |
| 1 stock pot (10 gallons; old) | .75 |

| | Depreciation. |
|---|---|
| 2 bread pans (12 by 24 inch, sheet iron) at $1.50 each | $1.25 |
| 2 bread pans (24 by 24 inch, sheet iron) at $1.75 each | .20 |
| 4 cooking spoons at 20 cents each | .45 |
| 1 ladle at 35 cents | .12 |
| 2 cooking forks at 10 cents each | .18 |
| 2 iron frying pans, 12 inches in diameter, at 35 cents each | .15 |
| 1 iron frying pan, 10 inches in diameter, at 25 cents | .07 |
| 1 enamel stew pan (1 gallon) at $1.25 | 1.20 |
| 1 kitchen range (second hand, $25) | 1.00 |
| 4 dish pans, 18 inches diameter, at $1.50 each | .51 |
| 10 enamel dish pans at 70 cents each | .32 |
| 38 cans potash at 5½ cents each | 2.09 |
| 102 bars brown soap at 2¾ cents per bar | 1.48 |
| 1 one-half bushel measure at 30 cents | .30 |
| 1 pint measure at 25 cents | |
| 1 quart measure at 25 cents | |
| 1 one-half gallon measure at 40 cents | |
| 6 galvanized buckets at 43½ cents each | 2.11 |
| 1 meat grinder | |
| 1 meat saw | |
| Total depreciation in 6 months | 21.99 |

The cost of this item for each of the 7,174 convict calendar days of the first 6 months of operation was therefore $0.0030.

### FUEL AND LIGHT.

The camp was heated by means of five wood stoves, there being two in the sleeping quarters, two in the mess room, and one in the office building. The fuel for these stoves was the wood cut from the right of way, and as it was cut and prepared by the convicts it does not enter as an item into the cost of maintenance. The amount used during the first 6 months was approximately 80 cords.

Light was furnished by kerosene lamps, which were filled and cleaned daily by a member of the camp force. During the first 6 months of operation 470½ gallons of kerosene were used, which, at the price of 11½ cents per gallon, amounted to $54.10.

Table 14 gives the complete costs of fuel and light chargeable to the maintenance of convicts and also the cost per man per calendar day.

TABLE 14.—*Costs of fuel and light from January 10 to July 10, 1916, Fulton County, Ga., Experimental Convict Camp.*

| | |
|---|---|
| 470.5 gallons kerosene, at 11½ cents per gallon | $54.10 |
| 6 searchlights, at $1.535 per light | 9.21 |
| 9 dozen boxes matches | .80 |
| Total cost from Jan. 10 to July 10 | 64.11 |
| Total number of convict calendar days from Jan. 10 to July 10 | 7,174 |
| Cost per convict per calendar day | $0.0089 |

## SUBSISTENCE.

Food was provided and served to the convicts in accordance with eight diet tables designed by the United States Public Health Service. These tables, 15 to 22, inclusive, were so arranged as to provide a maximum amount of nourishment at a minimum cost.

TABLE 15.—*Diet without fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| White flour (or Graham or whole-wheat flour) | 8 | 1.064 | 0.120 | 5.816 |
| Corn meal | 8 | .736 | .152 | 6.032 |
| Hominy (or oatmeal) | 2 | .166 | .012 | 1.580 |
| Salt fat pork | 8 | .592 | 5.320 | |
| Dried peas | 4 | .984 | .040 | 2.480 |
| Potatoes | 16 | .288 | .016 | 2.350 |
| Onions | 1 | .014 | .003 | .089 |
| Cheese | 3 | .776 | 1.010 | .072 |
| Dried fruit | 1.3 | .027 | | .933 |
| Sugar | 0.5 | | | .500 |
| Lard | 2 | | 2.000 | |
| Molasses | 2 | | | 1.400 |
| Vinegar | 1 | | | |
| Coffee | 0.4 | | | |
| Solids | 57.2 | 4.647 | 8.673 | 21.252 |
| Calories | | 527 | 2,213 | 2,410 |

Nutritive ratio, 1:9.1.

Breakfast:
- White or Graham biscuit.
- Hominy grits (boiled or fried).
- Fried salt pork, 3 ounces.
- Molasses, 2 ounces.
- Sugar, one-half ounce with coffee.
- Coffee, two-fifths ounce.

Dinner:
- Stewed peas.
- Corn bread.
- Salt fat pork, 4 ounces (stewed with peas).

Supper:
- Potatoes, 16 ounces.
- Onions, 1 ounce.
- Vinegar, 1 ounce. } Potato salad.
- Water, 1 ounce.
- Bacon, 1 ounce.
- Cheese, 3 ounces.
- Stewed fruit.
- White or Graham biscuit.

TABLE 16.—*Diet without fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| White flour (or Graham or whole-wheat flour) | 8 | 1.064 | 0.120 | 5.816 |
| Corn meal | 8 | .736 | .152 | 6.032 |
| Oatmeal (or hominy grits) | 2 | .322 | .144 | 1.350 |
| Dried peas | 4 | .984 | .040 | 2.480 |
| Salt fat pork (plates, backs, bellies, etc.) | 8 | .592 | 5.320 | .......... |
| Potatoes | 12 | .216 | .012 | 1.764 |
| Onions | 1 | .014 | .003 | .089 |
| Salt fish (herring, mackerel) | 5 | 1.025 | .440 | .......... |
| Dried fruit | 1.3 | .027 | .......... | .933 |
| Sugar | 0.5 | .......... | .......... | .500 |
| Lard | 2 | .......... | 2.000 | .......... |
| Molasses | 2 | .......... | .......... | 1.400 |
| Coffee | 0.4 | .......... | .......... | .......... |
| Solids | 54.2 | 4.980 | 8.231 | 20.364 |
| Calories | .......... | 565 | 2,100 | 2,309 |

Nutritive ratio, 1:8.2.

Breakfast:
- White or Graham biscuit.
- Oatmeal, mush, or grits.
- Fried pork, 4 ounces.
- Sirup, 2 ounces.
- Sugar, one-half ounce, with coffee.
- Coffee (1 cup), two-fifths ounce.

Dinner:
- Corn bread (from corn meal), 8 ounces.
- Stewed peas (from dried peas), 4 ounces.
- Boiled salt pork, 4 ounces (boiled with peas).

Supper:
- Broiled salt fish.
- Lyonnaise potatoes.
- Stewed fruit.
- White or Graham biscuit.

TABLE 17.—*Diet without fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| White flour (or Graham or whole-wheat flour) | 8 | 1.164 | 0.120 | 5.816 |
| Corn meal | 4 | .368 | .076 | 3.016 |
| Condensed milk | 1 | .096 | .093 | .112 |
| Oleo or fat | 1 | .012 | .830 | .......... |
| Rice | 2 | .160 | .006 | 1.580 |
| Onions | 1 | .014 | .003 | .089 |
| Potatoes | 24 | .432 | .024 | 3.528 |
| Cheese | 3 | .776 | 1.010 | .072 |
| Eggs | 4 | .524 | .372 | .......... |
| Salt fish | 5 | 1.025 | .440 | .......... |
| Dried fruit | 1.3 | .027 | .......... | .933 |
| Sugar | 0.5 | .......... | .......... | .500 |
| Lard | 2 | .......... | 2.000 | .......... |
| Molasses | 2 | .......... | .......... | 1.400 |
| Coffee | 0.4 | .......... | .......... | .......... |
| Solids | 59.2 | 4.598 | 4.974 | 17.046 |
| Calories | .......... | 522 | 1,269 | 1,933 |

Nutritive ratio, 1:6.1.

Breakfast:
Corn-meal mush (from 4 ounces corn meal).
Fried potatoes, 8 ounces.
White or Graham biscuits.
Molasses, 4 ounces.
Sugar, one-half ounce, with coffee.
Coffee (1 cup), two-fifths ounce.
Dinner:
Cheese, 3 ounces, } with bread, as sandwiches.
Fried eggs (2) }
Fried rice and onions.
Supper:
Broiled salt fish.
Potatoes, mashed, 16 ounces.
Stewed fruit.
White or Graham biscuits.

TABLE 18.—*Diet without fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| White flour (or Graham or whole-wheat flour) | 8 | 1.064 | 0.120 | 5.816 |
| Corn meal | 8 | .736 | .152 | 6.032 |
| Navy beans | 4 | .900 | .072 | 2.384 |
| Salt fat pork | 8 | .592 | 5.320 | |
| Macaroni | 2.4 | .322 | .022 | 1.778 |
| Cheese | 1.5 | .388 | .505 | .036 |
| Cabbage, turnips, other fresh vegetables | 12 | .168 | .024 | .576 |
| Dried fruit | 1.3 | .027 | | .933 |
| Sugar | 0.5 | | | .500 |
| Lard | 2 | | 2.000 | |
| Molasses | 2 | | | 1.400 |
| Coffee | 0.4 | | | |
| Solids | 50.1 | 4.197 | 8.215 | 19.455 |
| Calories | | 476 | 2,096 | 2,206 |

Nutritive ratio, 1:9.5.

Breakfast:
Hot wheat cakes.
Fried pork, 4 ounces.
Molasses, 2 ounces.
Sugar, one-half ounce, with coffee.
Coffee (1 cup), two-fifths ounce.
Dinner:
Baked beans, 4 ounces.
Salt fat pork, 4 ounces, baked with beans.
Corn bread (from 8 ounces corn meal).
Supper:
Baked macaroni and cheese.
Cabbage, or turnip, or other vegetable, 12 ounces.
Stewed fruit.
White or Graham biscuit.

Serve pickles with beans and vinegar with cabbage.

TABLE 19.—*Diet with fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| Fresh meat (as purchased) | 14 | 2.000 | 1.320 | .......... |
| White flour (or Graham or whole-wheat flour) | 16 | 2.128 | .240 | 11.632 |
| Rice | 2 | .160 | .006 | 1.580 |
| Hominy, oatmeal, or corn meal | 2 | .166 | .012 | 1.580 |
| Potatoes | 16 | .288 | .016 | 2.350 |
| Turnips | 1 | .009 | .001 | .057 |
| Carrots | 1 | .009 | .002 | .074 |
| Onions | 3 | .042 | .009 | .267 |
| Salt fat pork | 4 | .296 | 2.660 | .......... |
| Dried fruit | 1.3 | .027 | .......... | .933 |
| Sugar | 0.5 | .......... | .......... | .500 |
| Lard | 2 | .......... | 2.000 | .......... |
| Molasses | 2 | .......... | .......... | 1.400 |
| Coffee | 0.4 | .......... | .......... | .......... |
| Solids | 65.2 | 5.125 | 6.266 | 20.373 |
| Calories | .......... | 581 | 1,599 | 2,310 |

Nutritive ratio, 1:7.

Breakfast:

- Hominy, oatmeal, or corn-meal mush (from 2 ounces meal).
- Fried salt pork, 4 ounces.
- White or Graham bread or biscuit.
- Molasses, 2 ounces.
- Sugar, one-half ounce with coffee.
- Coffee, two-fifths ounce.

Dinner:

- Meat stew:
  - 14 ounces meat.
  - 16 ounces potato.
  - 1 ounce turnips.
  - 1 ounce carrots.
  - 1 ounce onions.
- White or Graham bread or biscuit.

Supper:

- Boiled rice (from 2 ounces rice).
- White or Graham bread or biscuit.
- Stewed fruit.

TABLE 20.—*Diet without fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| White flour (or Graham or whole-wheat flour) | 8 | 1.064 | 0.120 | 5.816 |
| Corn meal | 8 | .736 | .152 | 6.032 |
| Salt fat pork (plates, backs, bellies, etc.) | 8 | .592 | 5.320 | .......... |
| Navy beans | 4 | .900 | .072 | 2.384 |
| Potatoes (Irish or sweet) | 16 | .288 | .016 | 2.350 |
| Salt codfish | 5 | .950 | .020 | .......... |
| Dried fruit | 1.3 | .027 | .......... | .933 |
| Sugar | 0.5 | .......... | .......... | .500 |
| Lard | 2 | .......... | 2.000 | .......... |
| Molasses | 2 | .......... | .......... | 1.400 |
| Coffee | 0.4 | .......... | .......... | .......... |
| Solids | 55.2 | 4.557 | 7.700 | 19.415 |
| Calories | .......... | 517 | 1,965 | 2,202 |

Nutritive ratio, 1:8.3.

- Breakfast:
  - White or Graham biscuit.
  - Fried pork, 4 ounces.
  - Molasses, 2 ounces.
  - Sugar, one-half ounce, with coffee.
  - Coffee, 1 cup.
- Dinner:
  - Corn bread (from corn meal, 8 ounces).
  - Stewed beans (from dried beans, 4 ounces).
  - Boiled salt pork, 4 ounces (boiled with beans).
- Supper:
  - Stewed codfish (milk sauce).
  - Boiled potatoes, 16 ounces.
  - Stewed fruit.
  - White or Graham biscuit.

Fresh green vegetables or fruits, in season, cooked or uncooked, should be added to this diet; also pickles in reasonable quantities.

TABLE 21.—*Diet with corned beef or fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| Fresh fish or corned beef | 12 | 2.028 | 1.704 | .......... |
| White flour (or Graham or whole-wheat flour) | 16 | 2.128 | .240 | 11.632 |
| Hominy, oatmeal, or corn meal | 2 | .166 | .012 | 1.580 |
| Potatoes | 16 | .288 | .016 | 2.350 |
| Macaroni | 3 | .402 | .027 | 2.223 |
| Condensed milk | 2 | .192 | .186 | .224 |
| Oleo or fat | 0.5 | .......... | .470 | .......... |
| Onions | 3 | .042 | .009 | .267 |
| Dried fruit | 1.3 | .027 | .......... | .933 |
| Sugar | 0.5 | .......... | .......... | .500 |
| Lard | 2 | .......... | 2.000 | .......... |
| Molasses | 2 | .......... | .......... | 1.400 |
| Coffee | 0.4 | .......... | .......... | .......... |
| Solids | 60.7 | 5.273 | 4.664 | 21.109 |
| Calories | .......... | 598 | 1,190 | 2,396 |

Nutritive ratio, 1:6.0.

- Breakfast:
  - Boiled hominy, oatmeal, or corn meal (from 2 ounces dry meal).
  - Molasses, 2 ounces.
  - White or Graham bread or biscuit.
  - Coffee.
- Dinner:
  - Fresh fish, 12 ounces.
  - Boiled potatoes.
  - Boiled onions.
  - White or Graham bread or biscuit.
  - Or corned-beef hash:
    - Corned beef.
    - Potatoes.
    - Onions.
    - White or Graham bread or biscuit.
- Supper:
  - Boiled macaroni.
  - Milk sauce (for macaroni).
  - Stewed fruit.
  - White or Graham bread or biscuit.

TABLE 22.—*Diet without fresh meat.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. |
|---|---|---|---|---|
| | *Ounces.* | *Ounces.* | *Ounces.* | *Ounces.* |
| White flour (or Graham or whole-wheat flour) | 16 | 2.128 | 0.240 | 11.632 |
| Hominy, oatmeal, or corn meal | 2 | .166 | .012 | 1.580 |
| Kidney or navy beans | 4 | .900 | .072 | 2.384 |
| Salt fat pork | 8 | .592 | 5.320 | .......... |
| Cheese | 3 | .776 | 1.010 | .072 |
| Onions | 2 | .028 | .006 | .178 |
| Cabbage, or other vegetable except potatoes | 13 | .182 | .026 | .624 |
| Potatoes | 8 | .144 | .008 | 1.173 |
| Dried fruit | 1.3 | .027 | .......... | .933 |
| Sugar | 0.5 | .......... | .......... | .500 |
| Lard | 2 | .......... | 2.000 | .......... |
| Molasses | 2 | .......... | .......... | 1.400 |
| Coffee | 0.4 | .......... | .......... | .......... |
| Solids | 62.2 | 4.943 | 8.694 | 20.476 |
| Calories | .......... | 560 | 2,218 | 2,322 |

Nutritive ratio, 1:8.3.

Breakfast:
  White or Graham biscuit.
  Oatmeal, hominy, or corn meal (boiled or fried).
  Fried pork, 4 ounces.
  Molasses, 2 ounces.
  Sugar, one-half ounce with coffee.
  Coffee (1 cup), two-fifths ounce.
Dinner:
  Boiled cabbage, or other vegetable, 13 ounces.
  Boiled salt pork, 4 ounces (cooked with vegetables).
  White or Graham biscuit.
Supper:
  Dry stewed beans, mashed, 4 ounces.
  Grated cheese, 3 ounces.
  Bread crumbs, 3 ounces.
  Grated onion, 2 ounces.
  } Mix together, roll into loaf. Bake in oven.
  Baked potatoes, 8 ounces.
  Stewed fruit.
  White or Graham biscuit.

It was found necessary, in the course of the experiment, to make a few minor changes in the ration to suit the taste of the men, but in the main the tables were followed as designed. Table 23 shows the weight of the various items of food actually issued from January 10 to August 22, inclusive, the composition of the various foods and the food value consumed during the 6 months in calories per man per day.

TABLE 23.—*Food issued at experimental camp, January 10 to August 22, 1916.*

| Foodstuff. | Weight. | Proteins. | Fats. | Carbohydrates. | Cost. |
|---|---|---|---|---|---|
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | |
| Fresh beef | 600 | 98 | 59 | | $51.95 |
| Fresh pork | 514 | 69 | 124 | | 52.85 |
| Salt pork | 3,845 | 285 | 2,537 | | 502.25 |
| Fresh fish | 440 | 36 | 9 | | 14.37 |
| Salt cod fish | 38 | 10 | | | 6.30 |
| Salt herring | 657 | 135 | 58 | | 22.83 |
| Salt mackerel | 26 | 4 | 5 | | 2.44 |
| Flour | 7,068 | 995 | 134 | 5,237 | 163.52 |
| Corn meal | 3,167 | 291 | 60 | 2,385 | 59.31 |
| Macaroni | 288 | 39 | 3 | 214 | 17.54 |
| Grits | 207 | 17 | 1 | 169 | 4.28 |
| Rice | 255 | 20 | 1 | 201 | 11.51 |
| Oatmeal | 161 | 26 | 11 | 108 | 11.89 |
| Beans | 820 | 184 | 15 | 487 | 57.66 |
| Peas | 549 | 135 | 5 | 340 | 15.10 |
| Irish potatoes | 2,814 | 51 | 14 | 414 | 63.54 |
| Cabbage | 868 | 12 | 1 | 41 | 17.40 |
| Turnips | 35 | 4 | | 3 | .70 |
| Onions | 294 | 5 | 1 | 29 | 6.46 |
| Collards | 352 | 5 | | 10 | 3.52 |
| Prunes | 87 | 2 | | 64 | 6.61 |
| Dried fruit | 832 | 13 | 18 | 550 | 49.98 |
| Condensed milk | 103 | 10 | 10 | 11 | 11.80 |
| Sugar | 390 | | | 390 | 27.03 |
| Cheese | 271 | 69 | 80 | 10 | 50.37 |
| Molasses | 1,328 | | | 733 | 51.86 |
| Lard | 1,707 | | 1,707 | | 175.89 |
| Oleo | 22 | | 22 | | 4.29 |
| Salt | 416 | | | | 2.51 |
| Pepper | 10½ | | | | 2.01 |
| Baking powder | 331 | | | | 29.29 |
| Vinegar | 184 | | | | 3.92 |
| String beans | 675 | 21 | 2 | 67 | 13.50 |
| Coffee | 163 | | | | 17.47 |
| Pink beans | 130 | 29 | 2 | 77 | 10.40 |
| Lima beans | 100 | 18 | 1 | 66 | 7.00 |
| Total | | 2,583 | 4,880 | 11,803 | 1,549.35 |

Convict days, 8,862.
Calories per day, 51,178.
Cost per 1,000 calories, $0.033.
Cost per calendar day, $0.175.

The food was purchased by the county purchasing agent upon requisition made by the deputy warden and approved by the county warden. Perishable articles were purchased as used, but staples were kept on hand at all times. All food was inspected upon receipt at the camp to ascertain that it complied in quality and quantity with that ordered. In only a few instances were any discrepancies noticed and these were corrected at once.

A system of weighing and checking all food used was inaugurated and maintained, and this practice, coupled with the selection of the most efficient foods, is responsible for the low cost of subsistence.

The average cost of food furnished to convicts during the first six months, as shown by the detailed monthly report, was $0.175 per convict per calendar day. As an indication of the manner in which this food compared in cost and quality with that supplied by the county to the other county camps, Table 24 shows the character, amount, and cost of the rations furnished at the experimental camp from August 1 to August 22, inclusive, and the similar information regarding that served at the Lakewood fair grounds from August 23 to September 30, when the convicts were withdrawn from Government supervision. The rations listed in the second section of the table represent very closely the method of feeding followed by the county in its other camps. By comparing the two rations it is evident that while the calorific value of the ration served by the county was only about one-sixth greater than that supplied in the Government camp, the cost of the former for each 1,000 calories contained in the food was about 30 per cent greater than the latter. That the excess food value furnished by the county ration was unnecessary is shown by the fact that the convicts at the experimental camp, when questioned, invariably expressed themselves as fully satisfied with the character and amount of food supplied to them, and the greater efficiency of the foods comprising the diet of the experimental camp is evidenced by the lower cost per 1,000 calories.

TABLE 24.—*Comparison of cost of convict ration from August 1 to 22, 1916, inclusive, under Government supervision, and from August 23 to September 30, inclusive, under county supervision.*

| Under Government supervision. | | | | Under county supervision. | | | |
|---|---|---|---|---|---|---|---|
| Item. | Quantity used. | Unit cost. | Cost. | Item. | Quantity used. | Unit cost. | Cost. |
| Salt pork........pounds.. | 409 | .145 | $58.25 | Salt pork.......pounds.. | 1,261 | .145 | $182.85 |
| String beans........do.... | 75 | .02 | 1.50 | Green beans.......do.... | 90 | .02 | 1.80 |
| Salt herring.........do.... | 84 | .036 | 3.02 | Salt herring.........do.... | 216 | .036 | 7.78 |
| Flour................do.... | 610 | .025 | 15.25 | Flour................do.... | 340 | .025 | 8.50 |
| Meal.................do.... | 270 | .02 | 5.40 | Meal.................do.... | 1,176 | .02 | 23.52 |
| Macaroni............do.... | 32 | .0575 | 1.84 | | | | |
| Navy beans.........do.... | 67 | .0725 | 4.86 | | | | |
| Peas.................do.... | 50 | .0275 | 1.38 | Peas.................do.... | 170 | .0275 | 4.68 |
| Rice.................do.... | 20 | .045 | .90 | Green corn.........do.... | 182 | .20 | 36.40 |
| Potatoes............do.... | 195 | .02 | 3.90 | Sweet potatoes....do.... | 254 | .02 | 5.08 |
| Lima beans.........do.... | 40 | .07 | 2.80 | Lima beans.........do.... | 260 | .07 | 18.20 |
| Grits................do.... | 20 | .02 | .40 | | | | |
| Pink beans.........do.... | 40 | .08 | 3.20 | | | | |
| Oatmeal........packages.. | 15 | .0775 | 1.16 | | | | |
| Condensed milk....cans.. | 12 | .075 | .90 | | | | |
| Sugar............pounds.. | 34 | .08 | 2.72 | Sugar..............do.... | 57 | .08 | 4.56 |
| Cheese...............do.... | 31 | .17 | 5.27 | | | | |
| Coffee...............do.... | 18 | .11 | 1.98 | Coffee..............do.... | 118 | .11 | 12.98 |
| Molasses.........gallons.. | 14 | .32 | 4.48 | Molasses.........gallons.. | 11½ | .32 | 3.68 |
| Dried fruit.......pounds.. | 77 | .07 | 5.39 | Dried fruit......pounds.. | 63 | .07 | 4.41 |
| Lard.................do.... | 196 | .11 | 21.56 | Lard.................do.... | 114 | .11 | 12.54 |
| Baking powder......cans.. | 36 | .065 | 2.34 | Baking powder....cans.. | 78 | .065 | 5.07 |
| Salt..............pounds.. | 40 | .006 | .24 | Salt..............pounds.. | 73 | .006 | .44 |
| Pepper...............do.... | 2 | .19 | .38 | Pepper..............do.... | 1 | .19 | .19 |
| Vinegar.........gallons.. | 2 | .19 | .38 | Vinegar.........gallons.. | 1 | .19 | .19 |
| Total cost.......... | ........ | ........ | 149.50 | Total cost.......... | ........ | ........ | 332.87 |
| Total calories.............................. | | | 4,425,130 | Total calories.............................. | | | 7,503,680 |
| Total number convict days............... | | | 864 | Total number convict days............... | | | 1,260 |
| Cost of food per convict day............. | | | $0.1731 | Cost of food per convict day............. | | | $0.2642 |
| Cost per 1,000 calories..................... | | | .034 | Cost per 1,000 calories..................... | | | .043 |

## MEDICINE AND MEDICAL ATTENTION.

The county employs a regular physician to care for the health of the inmates of the county chain gangs and other institutions, and the experimental camp was included among the institutions under his care. His salary was $2,400 per year and in addition he was allowed the use of an automobile at an approximate cost of $250 per year. He made no regular visits to the camp, but always responded promptly when called; and it is probable, considering the populations of the various institutions, that the experimental camp received its full proportion of his services. As the average population of the experimental camp was approximately 7 per cent of the population of all institutions, it would seem that a fair estimate of the expense of the doctor's services to the camp would be 7 per cent of his salary and the cost of operating his automobile. For the first six months of operation this would amount to $92.75.

The character of medicine and the equipment of surgical instruments kept at the camp, the cost of medicine used from January 10 to July 10, and the depreciation of instruments, etc., during that period, are given in Table 25.

TABLE 25.—*Medical and surgical equipment of the Fulton County, Ga., Experimental Convict Camp, the cost of medicine used, and depreciation of instruments, January 10 to July 10, 1916.*

| Article. | Amount or number. | Unit cost. | Cost. | Expense of use and depreciation. |
|---|---|---|---|---|
| Tincture of capsicum ... ounces | 10 | $0.63 | $0.39 | $0.23 |
| Alum ... pounds | 4 | .06 | .24 | .24 |
| Absorbent cotton ... roll | 1 | .17½ | .17 | .17 |
| Do ... pound | 1 | .25 | .25 | .......... |
| 1 inch by 5 yards adhesive plaster ... spool | 1 | .30 | .30 | .30 |
| Adhesive plaster ... yards | 10 | .05 | .50 | .03 |
| 4 per cent aqueous solution boric acid ... ounces | 2 | .12½ | .25 | .......... |
| 3 per cent alcoholic solution iodine ... do | 2 | .12½ | .25 | .25 |
| Aromatic spirits of ammonia ... do | 2 | .07½ | .15 | .15 |
| Aspirin tablets, 5 grains | 100 | .90 | .90 | .......... |
| Enameled basin | 1 | .60 | .60 | .......... |
| 3 per cent bicarbonate of soda in petrolatum ... ounces | 6 | .05 | .30 | .......... |
| Bismuth subcarborate tablets, 5 grains | 100 | .91 | .91 | .91 |
| Boric acid ointment ... ounces | 8 | .90 | .45 | .......... |
| Brown's-mixture tablets | 500 | 1.76 | .88 | .66 |
| Calomel and soda tablets, ½ grain | 100 | .12 | .12 | .......... |
| Catgut sutures, assorted ... tubes | 3 | .20 | .60 | .......... |
| Soft rubber catheters | 2 | .20 | .40 | .40 |
| Chloroform liniment ... ounces | 16 | .75 | .75 | .75 |
| Compound cathartic pills ... do | 4 | 1.34 | .33 | .33 |
| Do | 500 | .21 | 1.05 | .28 |
| Eosol ... pint | 1 | .34 | .34 | .08 |
| Eye cup | 1 | .10 | .10 | .10 |
| Gauze bandage, 3 inches by 10 yards ... roll | 1 | .10 | .10 | .10 |
| Gauze bandage, 2 inches by 10 yards ... do | 1 | .10 | .10 | .10 |
| Gauze bandage, 1 inch by 10 yards ... do | 1 | .10 | .10 | .10 |
| Grain alcohol ... pint | ½ | .60 | .30 | .30 |
| Plain gauze ... yards | 5 | .06 | .30 | .......... |
| Green soap ... pound | 1 | .15 | .15 | .......... |
| 6-inch hæmostats | 4 | .90 | 3.60 | 3.60 |
| Hot-water bag | 1 | 1.00 | 1.00 | 1.00 |
| Hypodermic outfit | 1 | 2.00 | 2.00 | .......... |
| Tincture Jamaica ginger ... ounces | 2 | .07½ | .15 | .15 |
| Medicine droppers | 2 | .05 | .10 | .10 |
| Medicine glass | 1 | .10 | .10 | .10 |
| Mercurial ointment, U. S. P ... ounces | 8 | .09 | .72 | .36 |
| Nail brush | 1 | .05 | .05 | .05 |
| Opal silk ... packages | 2 | .25 | .50 | .......... |
| Potassium iodide solution ... ounces | 8 | .09½ | .75 | .......... |
| Probe | 1 | .30 | .30 | .30 |
| Quinine sulphate tablets, 5 grains | 100 | 1.15 | 1.15 | .86 |
| Rubber tourniquet | 1 | 1.00 | 1.00 | .......... |
| Safety pins, assorted sizes | 12 | .05 | .05 | .05 |
| Scalpels | 2 | .50 | 1.00 | 1.00 |
| 4½-inch scissors ... pair | 1 | .75 | .75 | .75 |
| Surgical scissors, 6½ inches ... do | 1 | 1.25 | 1.25 | 1.00 |
| Sodium bicarbonate ... pound | 1 | .15 | .15 | .15 |
| No. 1 splints | 2 | .50 | 1.00 | 1.00 |

TABLE 25.—*Medical and surgical equipment of the Fulton County, Ga., Experimental Convict Camp, the cost of medicine used, and depreciation of instruments, January 10 to July 10, 1916*—Continued.

| Article. | Amount or number. | Unit cost. | Cost. | Expense of use and depreciation. |
|---|---|---|---|---|
| Surgical forceps | 1 | $0.50 | $0.50 | $0.50 |
| Surgical needles ........dozen.. | 1 | .60 | .60 | ........ |
| Sulphate ointment ........ounces.. | 16 | .75 | .75 | ........ |
| Toothache drops ........do.... | 1 | .25 | .25 | ........ |
| Epsom salts ........pounds.. | 8 | .06 | .48 | .48 |
| Do ........ounces.. | 16 | .09 | .09 | .07 |
| Do ........pounds.. | 10 | .05 | .50 | .50 |
| Castor oil ........gallon.. | 1 | 2.70 | 2.70 | 2.70 |
| Do ........ounces.. | 16 | .40 | .40 | .40 |
| Spirits of niter ........pound.. | 1 | .47 | .47 | .47 |
| Turpentine ........pounds.. | 2 | .14 | .28 | .14 |
| Do ........ounces.. | 4 | .10 | .03 | .03 |
| Do ........do.... | 8 | .32 | .16 | .16 |
| "Mixed Treatment" pills | 300 | .45 | 1.33 | 1.33 |
| Do ........box.. | 1 | 3.65 | 3.65 | ........ |
| Cream liniment ........ounces.. | 12 | .02 | .24 | .24 |
| Liniment ........pound.. | 1 | .20 | .20 | .20 |
| Camphorine ........ounces.. | 4 | .02½ | .10 | .10 |
| Headache tablets | 200 | .20 | .40 | .30 |
| Sloan's liniment ........botles.. | 6 | .67 | 4.02 | ........ |
| Total | ........ | ........ | 44.05 | 23.57 |

The total cost of medicine, medical attention, etc., for the six months from January 10 to July 10 is shown by the above figures to be $116.32; and as there were 7,174 convict calendar days in that period, the cost of this item is $0.0162 per convict per calendar day.

## TRANSPORTATION OF CONVICTS AND SUPPLIES.

Food, supplies, and equipment were brought to the camp from Atlanta at least once a week by the camp team driven by a hired driver, who was paid at the rate of $1.35 per day for the time he was actually employed and allowed lodging and subsistence free at the camp. Convicts also were transported to and from the camp in the same manner, and a 1-horse team was employed to carry the midday meal to the men on the road. When they were not occupied in any of these ways both driver and team were assigned to the road work, to be employed in such manner as the foreman might direct.

Table 26 contains a statement of the time of the driver and team spent in transporting convicts, food, supplies, and equipment between January 10 and July 10.

TABLE 26.—*Cost of transporting convicts, food, supplies, and equipment from January 10 to July 10, 1916.*

| | |
|---|---|
| Free driver, 61 days, at $1.592 per day | $243.53 |
| Camp team, 127½ days, at $1.91 per day | $97.07 |
| Cost of transportation January 10 to July 10 | $340.60 |
| Number of convict calendar days, January 10 to July 10 | 7,174 |
| Cost of transportation per convict per calendar day | $0.0475 |

## CONVICT POPULATION.

### TERMS, CRIMES, AND CHARACTERISTICS.

The first 17 convicts assigned to the camp were taken from the county camp known as the "honor" camp. It has been mentioned that the inmates of this camp were chosen as a mark of honor for good behavior in other camps, but that they were allowed neither the liberties nor the privileges customarily granted to honor convicts. Subsequently, recruits were drawn from each of the other county camps upon the recommendation of the various deputy wardens that they were worthy of trust and deserving of the honor which promotion to the honor camp implied. The average daily population was 39.2. There is reason to believe that the men selected were not always either the most trustworthy or the most deserving of those eligible. The deputies in charge of the other camps manifested a natural desire to retain their best men. In fact, though the population of the experimental camp formed only about 7 per cent of the total convict population of the county, it is probable that fully 30 per cent would have responded successfully to the same discipline.

Table 27 contains a list of the crimes and sentences of all convicts assigned to the camp, and shows that the maximum sentence was 5 years, the minimum 3 months, and the average 12 months; while the average length of time served in the camp was about 6 months. It will be observed also that the majority of the crimes are such as might be presumed to indicate a lack of honesty and strong sense of honor in the criminals, and that only a comparatively small percentage are crimes of impulse. These facts are more clearly brought out in the analysis of crimes in Table 28.

TABLE 27.—*Terms and crimes of inmates, Fulton County, Ga., Experimental Convict Camp, January 10 to August 22, 1916.*

| Prison No. | Crime. | Sentence. | Time to serve when received. |
|---|---|---|---|
| | | *Years.* | *Months.* |
| 1 | Burglary | 5 | 3 |
| 2 | do | 5 | 2½ |
| 3 | do | 3 | 6 |
| | | *Months.* | |
| 4 | do | 16 | 5½ |
| 5 | do | 12 | 3½ |
| 6 | do | 12 | 3 |
| 7 | do | 12 | 3 |
| 8 | do | 12 | 2 |
| 9 | do | 12 | 1½ |
| 10 | do | 12 | 1 |
| 11 | do | 6 | 6 |
| 12 | Robbery | 12 | 9 |
| 13 | do | 12 | 8 |
| 14 | do | 12 | 5 |
| 15 | do | 12 | 5 |
| 16 | Larceny | 36 | 15 |
| 17 | do | 24 | 13 |
| 18 | do | 24 | 9½ |
| 19 | do | 16 | 6 |
| 20 | do | 12 | 9 |

TABLE 27.—*Terms and crimes of inmates, Fulton County, Ga., Experimental Convict Camp, January 10 to August 22, 1916.*—Continued.

| Prison No. | Crime. | Sentence. | Time to serve when received. |
|---|---|---|---|
| | | *Months.* | *Months.* |
| 21 | Larceny | 12 | 7 |
| 22 | do | 12 | 3 |
| 23 | do | 12 | 2 |
| 24 | do | 11 | 8 |
| 25 | do | 10 | 7½ |
| 26 | do | 10 | 5½ |
| 27 | do | 10 | 5 |
| 28 | do | 8 | 7 |
| 29 | do | 8 | 5 |
| 30 | do | 8 | 3½ |
| 31 | Larceny after trust | 10 | 3½ |
| 32 | Larceny from house | 32 | 30 |
| 33 | do | 16 | 9 |
| 34 | do | 12 | 10½ |
| 35 | do | 12 | 9½ |
| 36 | do | 12 | 9 |
| 37 | do | 12 | 8 |
| 38 | do | 10 | 8½ |
| 39 | do | 10 | 7½ |
| 40 | do | 10 | 6 |
| 41 | do | 8 | 8 |
| 42 | do | 8 | 8 |
| 43 | do | 8 | 8 |
| 44 | Bought watch on installment plan and sold it | 16 | 2 |
| 45 | do | 8 | 1 |
| 46 | Larceny from car | 12 | 8½ |
| 47 | Appropriated bacon he was delivering and sold it | 12 | 6 |
| 48 | Kept money collected in trust | 12 | 2½ |
| 49 | Stealing | 12 | 6½ |
| 50 | Gaming | 14 | 11 |
| 51 | do | 12 | 6½ |
| 52 | do | 12 | 1 |
| 53 | do | 12 | 1 |
| 54 | do | 12 | 1 |
| 55 | do | 10 | 5½ |
| 56 | do | 8 | 7 |
| 57 | do | 8 | 7 |
| 58 | do | 8 | 3 |
| 59 | do | 8 | 3 |
| 60 | do | 6 | 5 |
| 61 | do | 6 | 5 |
| 62 | do | 6 | 5 |
| 63 | do | 6 | 3 |
| 64 | do | 6 | 1 |
| 65 | do | 6 | 1 |
| 66 | Selling liquor without license | 12 | 5 |
| 67 | do | 10 | 8½ |
| 68 | do | 10 | 3½ |
| 69 | do | 8 | 6½ |
| 70 | do | 6 | 5 |
| 71 | Vagrancy | 12 | 11 |
| 72 | do | 12 | 8 |
| 73 | do | 10 | 5 |
| 74 | Abandoning children | 12 | 1½ |
| 75 | Carrying concealed weapon | 12 | 8 |
| 76 | do | 8 | 6½ |
| 77 | do | 8 | 5 |
| 78 | do | 6 | 6 |
| 79 | do | 6 | 3 |
| 80 | Wife beating | 8 | 4 |
| 81 | Adultery | 12 | 9 |
| 82 | Stabbing | 12 | 8 |
| 83 | do | 12 | 7 |
| 84 | do | 12 | 7 |
| 85 | do | 12 | 2½ |
| 86 | do | 12 | 1 |
| 87 | do | 11 | 6½ |
| 88 | do | 10 | 1 |
| 89 | do | 8 | 7 |
| 90 | do | 8 | 2 |
| 91 | do | 6 | 3 |
| 92 | do | 12 | 7 |
| 93 | do | 3 | 3 |
| 94 | Assault and battery | 8 | 7 |
| 95 | Violation of probation | [1]4 | 2 |
| 96 | Assault to rape | 12 | 11 |

[1] And 19 days.

TABLE 28.—*Analysis of crimes of inmates, Fulton County, Ga., Experimental Convict Camp, January 10 to August 22, 1916.*

| Kind of crime. | Number. |
|---|---|
| Against property | 49 |
| Against the person | 15 |
| Against public order | 32 |
| Total | 96 |
| Percentage against property | 51.0 |
| Percentage against the person | 15.6 |
| Percentage against public order | 33.4 |
| Total | 100.0 |

In view of these characteristics it is somewhat surprising that there were no attempts to escape and that there were only nine offenses against the order of the camp. A list of these offenders is given in Table 29.

TABLE 29.—*Offenders and offenses against the order of the camp.*

| Prison No. | Crime for which convicted. | Offense. | Prison No. | Crime for which convicted. | Offense. |
|---|---|---|---|---|---|
| 46 | Larceny from car | Fighting. | 96 | Assault to rape | Unsatisfactory work. |
| 68 | Selling liquor without license. | Do. | 72 | Vagrancy | Do. |
| 10 | Burglary | Do. | 30 | Larceny | Cursing officer. |
| 12 | Robbery | Do. | 1 | Burglary | Stealing sugar. |
| 71 | Vagrancy | Unsatisfactory work. | | | |

The general facts that all inmates were negroes and that practically all were from the city of Atlanta have been mentioned.

### OFFICERS: NUMBER, SALARIES, AND DUTIES.

The county warden, as the representative of the State prison commission and the board of county commissioners, was in general charge of all camps and prisoners in the county, and it is estimated that about one-tenth of his attention was devoted to the experimental camp. Five officers under this official were in immediate control of the camp. Their positions and respective salaries were as follows:

| | Per month and board. |
|---|---|
| 1 deputy warden | $75 |
| 1 camp clerk | 50 |
| 1 foreman | 60 |
| 1 foreman | 40 |
| 1 nightwatchman | 40 |

The deputy warden was the highest camp officer and was responsible for the conduct and discipline of the camp and the satisfactory prosecution of the road work. However, about three-fourths of his time was devoted to the supervision of the road work, and therefore only one-fourth of his salary and the cost of his board have been reckoned in the cost of maintaining the camp.

The camp clerk acted as the deputy warden's assistant in the management of the camp, and in the absence of that officer was in full charge of the camp. It also was his duty to keep all camp records, to prepare all requisitions for supplies with the approval of the deputy, and to receive such supplies when delivered. He was in full charge of the commissary and of the issuing of food and supplies to the cook, foremen, etc. His entire salary and the full cost of his board are properly chargeable against the cost of camp maintenance.

The work of the night watchman is implied by the name. He entered upon his duties each day with the return of the convicts from the road work and remained responsible for the safety of the camp property and the security of the convicts until the force was sent to work again in the morning. His entire salary and the expense of his board are chargeable against the maintenance cost.

The two foremen were in charge of parts of the road work under the deputy warden. Incidentally, of course, they exercised a reasonable surveillance over the convicts, but as the work could not have been carried on successfully with less than two foremen, and as their duties resembled those of foremen in charge of squads of free workmen more closely than those of convict guards, it is believed that their salaries and board are properly chargeable to the construction work.

None of the officers was armed in any way.

The cost of camp supervision for the months from January 10 to July 10 are shown in Table 30.

TABLE 30.—*Costs of camp supervision from January 10 to July 10, 1916, Fulton County, Ga., Experimental Convict Camp.*

| | |
|---|---|
| Deputy warden, 45¾ days, at $2. 724 | $124. 64 |
| Camp clerk, 183 days, at $1. 897 | $347. 20 |
| Night watchman, 179 days, at $1. 568 | $280. 67 |
| Total cost Jan. 10 to July 10 | $752. 51 |
| Total number of convict calendar days | 7, 174 |
| Cost of camp supervision per convict per calendar day | $0. 1049 |

### HEALTH OF THE CONVICTS.

All candidates for the camp underwent a thorough physical examination before they were accepted to determine that they had no physical defects or infirmities which would render them unfit for road work or cause them to be a menace to the health of other prisoners. The examinations of the first 48 men assigned were made by an officer of the public health service, the others were examined by the county physician. Convicts too weak to be of service in the camp were refused admittance; others whom the examination showed to be suffering with infectious diseases also were included. Those accepted were little if any above the average standard of the entire county force in physical condition. This is indicated in a measure by the fact that 35 per cent of those accepted gave a history or showed positive evidence of disease in an infectious form.

The character and amount of the general medical attention received by the inmates after assignment are described under the heading "Medicine and Medical Attention." In August, 1916, the services of the county physician were supplemented by the appointment of a dentist to visit the camps. The cost of this service was small, as the dentist engaged was a recent graduate who was willing to accept the opportunity to acquire experience as part payment for his work. Though this step was taken upon the advice of the officer representing the Public Health Service, the doctor was not appointed until the cooperative arrangement was about to be terminated, and for this reason the small cost does not appear in the statement of medical expense for the first 6 months of operation.

Complete records were kept of the diagnosis, duration, and treatment of each case of illness or injury that occurred in the camp. The analysis of these records contained in Table 31 shows that none of the illness was serious, and also shows the number of days' labor lost on account of the various indispositions from January 10 to July 10 and from July 11 to August 22. The table shows that 31 days were lost on account of sickness during the first inventory period. As there were 7,174 convict calendar days in the period the percentage of time lost on this account was 0.43 of 1 per cent. From July 11 to August 22, the percentage was somewhat larger on account of the large number of injuries.

TABLE 31.—*Analysis of sick record.*

| Diagnosis. | January 10 to July 10. | | | July 11 to August 22. | | |
|---|---|---|---|---|---|---|
| | Labor lost on account of— | | | Labor lost on account of— | | |
| | Injury. | Illness. | Malingering. | Injury. | Illness. | Malingering. |
| | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* | *Days.* |
| Cold | | 4 | | | 1 | |
| Sore eyes | 2 | 1 | | 2 | | |
| Kicked by mule | 2 | | | | | |
| Toothache | | 3 | | | | |
| Neuralgia | | 3 | | | | |
| Cramps | | 3 | | | 2 | |
| Overheated | | 3 | | | 5 | |
| Mashed finger | 1 | | | | | |
| Pain in back | 1 | | | 1 | | 1 |
| Indigestion | | | | 2 | | |
| Sore arm | 1 | | | | | |
| Boil | | | | | 2 | |
| Biliousness | | 2 | | | 4 | |
| Chills and fever | | | | | 3 | |
| Cut leg | | | | 11 | | |
| Rheumatism | | 5 | | | | |
| Total | 7 | 24 | | 16 | 17 | 1 |

## DISCIPLINE AND MORALE.

The methods of discipline contrasted sharply with those practiced in the other camps of the county, State, and section. So far as can be learned, similar methods never have been applied in any convict camp in the South, and for this reason the success of the system is one of the most striking and important results of the experiment which demonstrates conclusively that there is no foundation for the belief that negro convicts are amenable only to the discipline of locks, shackles, and lash.

In this camp no guard was armed and no convict was shackled; the only building locked night or day was the commissary. Plain gray clothing was substituted for convict stripes, and the use of the whip was prohibited. In place of these negative measures order, security, and obedience were obtained by the positive measures of attractive food, light, airy quarters, clean and comfortable beds, kind treatment, and greater privileges. During the day on the work the constant menace of the gun was removed, and the men worked under the foremen as freemen work. Whereas the practice in the other camps is to put the men "on the chain" immediately after the evening meal, in this camp they were permitted to remain outside the buildings, reading, smoking, playing quoits or baseball until dark, or in the mess room to enjoy a phonograph which was provided for them. Saturday afternoons, during the summer, were holidays, and the time was devoted to baseball and other games.

Minor infractions of the rules, disobedience, and unsatisfactory work were punished by demeriting the offender. When the number of such demerits exceeded the established limit the convict was returned to the county headquarters camp to be placed again under the more rigid discipline of one of the other camps. Serious offenses were punished by immediate return to headquarters camp with a recommendation that severe punishment be administered there. Attempted escape would have been punished in a similar manner, but it was unnecessary to administer any punishment for this cause during the entire period of cooperation, and as late as November 23, ten months after the opening of the camp, there still had not been a single attempt to escape.

Eight of the nine offenders listed in table 29 were punished by return to the guarded camp. Convict No. 1 was the camp cook. His offense was committed just before his discharge, and the sugar was not missed until the monthly inventory was taken.

The full measure of the success of the system of discipline is realized when it is understood that no attempt was made to hold the men by rewards of money or allowances of "good time" greater than those granted to other county convicts. The only measure of this kind was the granting of the customary ration of tobacco. From January 10 to July 10, inclusive, the expense for this privilege was $58.32, the cost of 243 pounds of tobacco at 24 cents per pound. As this expense was distributed over 7,174 convict calendar days, the cost per convict per calendar day was $0.0081. The tobacco was used at the rate of about one-quarter pound per convict per week.

The morale of the force was excellent. With few exceptions the men were content with the treatment they received, and freely expressed their appreciation of it, not only in words, but in a willingness to work and a prompt response to orders, such as is observed seldom in convict camps.

### THE CAMP FORCE.

The camp force consisted normally of three men, a cook, a cook's helper, and a "flunky." Under extraordinary conditions, such as immediately after the establishment of the camp when there was much cleaning to be done, it was necessary to increase the number. An average of seven men were thus employed for a period of about 2 weeks in the first 6 months, but for the rest of the time the three men performed all the necessary work. It should be observed, however, that no laundering was done at the camp and that the general camp work was also somewhat lighter than in the majority of camps, because it was not necessary to carry the water and dispose of the wastes by burial. It would have required at least one more camp helper to care for this additional work. During the first 6 months 659 convict calendar days were used on camp work, which represents a loss to the road work of 9.19 per cent.

### SANITATION.

The camp clerk was charged with responsibility for the sanitary condition of the camp and the direction of the work of the camp force. The kitchen and mess room were cleaned daily by the cook and his helper, and they presented a clean and neat appearance at all times. The bunk house and other buildings and the grounds were cleaned and kept in order by the camp "flunky." Particular attention was paid to the toilets, spittoons, and bedding, which were kept surprisingly clean. The floors were treated once every 2 weeks with an agglutinative oil dressing which enabled them to be swept daily without raising dust.

Though the interior of the buildings was kept scrupulously clean from the start, the importance of keeping the grounds in the same condition was not realized at first by local officials. They were permitted to become littered with tin cans, paper, wood, and other débris, particularly in the vicinity of the commissary and the corral, and it was only by systematic coaching and inspection that this condition was improved.

While the camp was in course of construction at the first site an inspection was made by an officer assigned by the Public Health Service, who outlined plans for sanitation. These included the protection of the well which called for the construction of a water-tight concrete casing to extend 4 feet below the surface and 18 inches above the ground, a concrete shield covering the ground around the well for a distance of 3 or 4 feet, and a water-tight cover of matched boards. The well was not constructed exactly in accordance with his instructions, and the protection provided was somewhat inadequate. The concrete casing was extended only 2 feet below and 6 inches above the ground surface, and no shield was provided, but in its place a ditch was dug around the well about 4 feet outside of the casing. The wooden cover was provided, as recommended, and a fence was erected around the well to prevent walking over the cover.

With the coming of the summer the flies became numerous and troublesome. They undoubtedly had their origin in the mule corral and it is probable that their numbers would have been reduced greatly by the application of borax to the manure, as suggested by the Public Health Service, but it was impossible either to convince the county authorities that the corral was the source or to persuade them to try the treatment recommended. It is true that the large surface area of the corral, over the entire extent of which the animal droppings were scattered, might have rendered the complete extermination of the flies impracticable, but the treatment would have bettered the conditions greatly. The screens in the windows and doors did not protect the interiors of the buildings. The flies came in when the doors were opened, and they collected in large numbers, particularly in the kitchen. When, finally, the abatement of the nuisance received the serious consideration of the county authorities, flytraps were constructed and fly paper was used liberally. These measures served to improve the conditions, but this phase of the experiment, at best, can not be regarded as a success.

The failures recited above are mentioned as matters of fact, but it should not be supposed that the sanitary conditions, as a whole, were bad. On the contrary, the camp presented an unusually clean and well-kept appearance, and even in respect to the fly nuisance it is quite likely that the conditions were somewhat better than the average.

The cost of caring for the camp is not reckoned as a part of the cost of maintaining the convicts themselves, and the direction of their labor by the camp clerk is charged under the head of camp supervision.

## RECORDS AND REPORTS.

The records and reports of the camp were kept on forms similar to those suggested in United States Department of Agriculture Bulletin No. 414, which are here reproduced. For a full discussion of the purpose of the various forms and the manner of keeping them the reader is referred to the former publication.

Form No. 1.1.

.................................... CONVICT ROAD FORCE.
(*Name of county or State.*)

**REQUISITION.**

Requisition No. ......
Supplies to be sent to....................................
(*Place.*)
Not later than.................................., 191..
Camp No. ......
Date of requisition.................................191..

| Quantity. | Article. | Quantity issued last month (or week). | Quantity on hand. | Order No. |
|---|---|---|---|---|
| | | | | (Not to be filled by Supt.) |

I certify that the quantities on hand and issued are correctly reported, the above articles are required, and the quantities are not excessive.

Approved: ................................, Warden. ................................, Supt.

1. Use different colored sheets for requisitions for food supplies and general supplies.
2. Whenever an emergency purchase is made locally, fill out this requisition form covering the purchase, write the word "Emergency" on it, and mail it with the bill to the warden.
3. If the article is unusual, explain the need for it on the requisition.

FORM 1. SIZE, 8 BY 10½ INCHES.

Form No. 1.2.

.................................... CONVICT ROAD FORCE.
(*Name of county or State.*)

**PURCHASE ORDER.**

Order No. ...... To Fill Requisition No. ...... From Camp No. ................

................................, ....................., 191..
(*Name of city or town.*)

Firm name ................................................
Address ................................................

Please ship the following articles to ................................
......................................................, via....................................,
and render the bill on the inclosed voucher form to ..................................................
................................................

Signature ................................................
(*Purchasing Agent or Official in Charge.*)

| Quantity. | Name of article. | Contract reference. |
|---|---|---|
| | | |

FORM 2. SIZE 8 BY 10½ INCHES.

Form No. 1.3. Voucher No........

..............................CONVICT ROAD FORCE.
(*Name of county or State.*)

**VOUCHERS FOR SUPPLIES AND SERVICES FURNISHED.**

Date, ......................, 191..

..................................
(*Name of county or State.*)

To...............................................Dr.

Goods supplied on
Purchase Order No...... Address.............................................
For Camp No...... ...........................................................

(Consult instructions on other side before preparing voucher.)

| Contract reference or authority. | Articles or service. | Quantity. | Unit | Unit price. | Amount. | | (Leave blank.) |
|---|---|---|---|---|---|---|---|
| | | | | | Dollars. | Cts. | Account. |
| | | | | | | | |
| | | | | | | | |

I certify that the above bill is correct and just, and that payment therefor has not been received.

(Payee sign here)..............................
Title....................................

I certify that the above articles have been received by me in good condition and in the quality and quantity specified, or that the services were performed as stated.

Signature..........................................Supt.

Approved for $ Signature.......................................Warden.

Paid by check No......, dated..........................., 191...

FORM 3. SIZE, 8 BY 10½ INCHES.

---

Form No. 1.4. Sheet No......

....................................CONVICT ROAD FORCE.
(*Name of county or State.*)

**INVENTORY OF PROPERTY.**

Camp No........ Place.................................., Date................, 191..

Listed by.............................................

| Quantity. | Item. | Description (Dimensions, materials, etc.). | Date of purchase. | Date received here. | Original value. | Present value. | Condition. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | Total, | | | |

FORM 4. SIZE, 8 BY 10½ INCHES.

Form No. 2.1.

............................................................CONVICT ROAD FORCE.
(*Name of county or State.*)

**Ration report.**

Month of..............................................................................

Camp No..............................................................................

Place....................................................................................

Signature.............................................................................
*Supt.*

Food item...........................................................

Usual ration........................................................

| | | |
|---|---|---|
| On hand first of month..................<br>Received during month. (Give date of receipt and unit cost of each shipment.) | | |
| Total to be accounted for................ | | |

| Issued to— | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Convicts.......... | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Officers.......... | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Waste.......... | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total issued. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Remarks: (State cause of waste; make statement of amount of food donated and raised, and give dates and manner of use. Food received but later returned should be deducted from amount received during month, and reason for return stated below.)

Should be on hand at end of month..............
Inventory at end of month..........................
Adjusted total issued to convicts..................
Adjusted total issued to officers...................
Average unit cost of food used by convicts.......
Average unit cost of food used by officers........
Total cost of convicts' food.........................
Total cost of officers' food..........................

FORM 5. SIZE, 8 BY 12½ INCHES.

Form No. 2.2.

................................, CONVICT ROAD FORCE.
(*Name of county or State.*)

**SUMMARY OF QUANTITIES AND COSTS OF FOOD ISSUED.**

Month of ................................

Camp No. ............ Place ........................ ...................., Supt.

| Item. | Quantity. | | Unit. | Unit cost. | Total cost. | | Days. | Number persons fed. | |
|---|---|---|---|---|---|---|---|---|---|
| | Con. | Off. | | | Convicts. | Officers. | | Convicts. | Officers. |
| | | | | | | | 1 | | |
| | | | | | | | 2 | | |
| | | | | | | | 3 | | |
| | | | | | | | 4 | | |
| | | | | | | | 5 | | |
| | | | | | | | 6 | | |
| | | | | | | | 7 | | |
| | | | | | | | 8 | | |
| | | | | | | | 9 | | |
| | | | | | | | 10 | | |
| | | | | | | | 11 | | |
| | | | | | | | 12 | | |
| | | | | | | | 13 | | |
| | | | | | | | 14 | | |
| | | | | | | | 15 | | |
| | | | | | | | 16 | | |
| | | | | | | | 17 | | |
| | | | | | | | 18 | | |
| | | | | | | | 19 | | |
| | | | | | | | 20 | | |
| | | | | | | | 21 | | |
| | | | | | | | 22 | | |
| | | | | | | | 23 | | |
| | | | | | | | 24 | | |
| | | | | | | | 25 | | |
| | | | | | | | 26 | | |
| | | | | | | | 27 | | |
| | | | | | | | 28 | | |
| | | | | | | | 29 | | |
| | | | | | | | 30 | | |
| | | | | | | | 31 | | |
| | | | | | | | Number of visitor-food days. | | |
| | | | | | | | Daily cost of food. | | |
| | | | | | | | Per convict. | | Per officer. |
| | | | | | | | | | |
| Grand total cost........ | ...... | ...... | ...... | ...... | ......... | ......... | ............ | | ............ |

FORM 6. SIZE, 8 BY 12½ INCHES.

Form 2.3.

...................... CONVICT ROAD FORCE.
(*Name of county or State.*)

**REPORT OF SERVICES AND SUPPLIES OTHER THAN FOOD.**

Camp No. ........................................
Place ..............................................
Signature ........................................
*Supt.*

Account ..........................................
Month of ..................................., 191..
Number of convict days since last inventory to first of month.
..................................................
Number of convict days this month ..............
Total number of convict days to date ............

| | | | | | |
|---|---|---|---|---|---|
| Date. | Item. | Last inventory value plus subsequent purchases to first of month .................... | | | $ |
| | | Purchased during month. | | | |
| | | Quantity. | Unit cost. | Total cost. | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| ....... | .................................................. | ........... | ........... | ....... | |
| | Total for month........................................ | | | | $ |
| | Grand total.............................................. | | | | $ |

FORM 7. SIZE, 8 BY 12½ INCHES.

Form No. 3.1.

........................................
(*Name of county or State.*)

CONVICT ROAD FORCE.

**DAILY REPORT OF CONSTRUCTION.**

Name of camp........................................
Name of place........................................
Name of road........................................
Kind of road........................................
Date........................................
Weather........................................
Name of supt........................................

FORCE REPORT.

| | Title. | Rate per day. | Effective labor days. | | | | | | | | | | | | | | | | | | Lost labor days. | | | | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Rock excavation. | Loose rock excavation. | Earth excavation. | Excavation for culverts and bridges. | Laying pipe. | Mixing and placing concrete. | Quarrying rock. | Crushing rock. | Loosening surface. | Loading surface material. | Hauling surface material. | Spreading surface material. | Sprinkling. | Rolling. | Mixing sand-clay. | Dragging. | Clearing and grubbing. | General. | Bad weather. | Sundays and holidays. | Sick. | Camp duty. | |
| Superintendence. | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hired labor. | | | | | | | | | | | | | | | | | | | | | | | | | |
| Convicts. | | | | | | | | | | | | | | | | | | | | | | | | | |
| Teams. | | | | | | | | | | | | | | | | | | | | | | | | | |

REPORT OF MATERIALS USED.

| Item. | Quantity. | Rate. | Amount. | Account. |
|---|---|---|---|---|
| | | | | |

PROGRESS REPORT.

| Activity. | Worked to-day. | | Completed. | |
|---|---|---|---|---|
| | Station to station. | | Station to station. | |
| | | | | |

FORM 8. SIZE, 8 BY 10½ INCHES.

Form No. 3.2.

........................................CONVICT ROAD FORCE.
(*Name of county or State.*)

**REPORT OF CONSTRUCTION.**

Account........................................., Month of......................., 191..

Name of road..............Kind of road............Camp No...Place............Signature..............

| Date. | Superintendence. | | | | Hired labor. | | | | | | | | Teams. | | Convict labor. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | |
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| 16 | | | | | | | | | | | | | | | |
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| 18 | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | |
| Total days, | | | | | | | | | | | | | | | |
| Wage | | | | | | | | | | | | | | | Assumed rate. |
| Board | | | | | | | | | | | | | | | Assumed amount. |
| Total rate | | | | | | | | | | | | | | | Actual rate. |
| Total amount | | | | | | | | | | | | | | | Actual amlount. |

MATERIALS USED.

| Item. | Quantity. | Rate. | Cost. | Item. | Quantity. | Rate. | Cost. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| Carried forward, | | | | Total cost, | | | |

TABLE OF UNIT COSTS.

| Activity. | Quantity. | Units. | Total cost materials. | Assumed labor cost. | Actual labor cost. | Approximate unit cost. | Actual unit cost. | Unit. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

FORM 9. SIZE, 12½ BY 16 INCHES.

Form No. 4.1.

................................, CONVICT ROAD FORCE.
(*Name of county or State.*)

**PRISONERS' TIME SHEET.**

Camp No. .......... Place, ........................ Month of ................, 191..

Signature, ..............................., Supt.

| Prison No. | Name. | Days on road. | Days camp duty. | Days bad weather. | Days of sickness. | Days, Sundays and holidays. | Total number days. |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | Total carried forward.................. | .......... | .......... | .......... | .......... | .......... | .......... |

FORM 10. SIZE, 8 BY 10½ INCHES.

Form No. 4.2.

................................, CONVICT ROAD FORCE.
(*Name of county or State.*)

**MOVEMENT OF PRISONERS.**

Camp No. .......... Place, ........................ Month of ..................., 191..

Signature, .................................., Supt.

On hand first day of month........................................ .............
Received during month........................................ .............
Recaptured and returned during month........................................ .............
To be accounted for........................................ .............
Discharged........................................ .............
Pardoned or paroled........................................ .............
Died........................................ .............
Escaped during month, and still at large........................................ .............
Sent to........................................ .............
........................................ .............
........................................ .............
Convicts on hand at end of month........................................ .............
Total (should agree with total above)........................................ .............
Remarks:

FORM 11. SIZE, 8 BY 10½ INCHES.

Form No. 4.3.

................................, CONVICT ROAD FORCE.
(*Name of county or State.*)

**DAILY REPORT OF SICKNESS.**

No. of camp........................................
Place........................................
Date of illness........................................
Day of illness (as 1st, 2d, 3d, etc.)........................................
Name of convict........................................
Of what does the convict complain?........................................
What signs of sickness did he show to-day?........................................
What treatment was given to-day?........................................
Was he seen by the doctor to-day?........................................
Doctor's diagnosis to-day........................................
Signature of superintendent........................................

FORM 12. SIZE, 8 BY 10½ INCHES.

All the reports were prepared without difficulty by the camp clerk, and the information was presented in such form as to render the segregation of costs for the various items herein reported comparatively simple.

A supply of the forms sufficient to serve the camp of 40 men for a period of about 2 years was printed for $95. The cost for the period from January 10 to July 10 therefore was less than $25. As the other duties of the camp clerk were of sufficient importance to have required such an official, even if the records had not been kept, the sole additional expense chargeable to the system of cost keeping for the 6-month period was this cost of $25. To indicate the value of the reports properly kept and used, it is necessary to state only that the saving on food alone made possible by the use of the forms during the period amounted to more than $350.

## SUMMARIZED COSTS OF MAINTENANCE.

The various items entering into the maintenance of the convicts have been fully described in the foregoing paragraphs, and the cost of each has been stated on the basis of a convict calendar day. These costs are now summarized in Table 32, which shows that the total cost of maintaining one convict one calendar day during the period from January 10 to July 10 was 55.09 cents.

TABLE 32.—*Cost of maintaining convicts.*

| Item. | Cost of maintenance per convict per calendar day. | Proportion of total. | Item. | Cost of maintenance per convict per calendar day. | Proportion of total. |
|---|---|---|---|---|---|
| | *Cents.* | *Per cent.* | | *Cents.* | *Per cent.* |
| Preparation of site | .36 | 0.7 | Fuel and light | .89 | 1.6 |
| Interest and depreciation on buildings | 6.23 | 12.4 | Subsistence | 17.47 | 31.7 |
| Water supply | 1.71 | 3.1 | Medicine and medical attention | 1.62 | 2.9 |
| Sewage disposal | .57 | 1.0 | Transportation | 4.75 | 8.7 |
| Clothing | 4.12 | 7.5 | Camp supervision | 10.49 | 19.0 |
| Laundry | 2.26 | 4.1 | Tobacco | .81 | 1.5 |
| Furniture and equipment | 2.91 | 5.3 | | | |
| Kitchen and mess equipment | .30 | 0.5 | Total | 54.49 | |

To obtain the cost of maintaining one working convict one working day, which is equivalent to the wage of the labor, it is necessary to modify the above cost by dividing it by the percentage of time actually applied to the work after deductions have been made for bad weather, Sundays and holidays, camp duty, and sickness. The losses are shown clearly by the camp reports and are given in table 33 in terms of convict days and percentages of the total available time of 7,174 convict days.

TABLE 33.—*Convict labor lost to road work.*

| Cause. | Convict days. | Percentage of time lost. |
|---|---|---|
| Bad weather | 371 | 5.17 |
| Sundays and holidays | 1,056.5 | 14.72 |
| Camp duty | 659 | 9.19 |
| Sickness | 31 | .43 |
| Total | 2,117.5 | 29.51 |

It appears from the above table that only 70.49 per cent of the total time of the convicts in the camp was applied to the road work. Therefore it is evident that the cost of maintaining one working convict one working day is

$$54.49 \div .70.49 = 77.30 \text{ cents.}$$

## ROAD WORK.

While the camp was under the observation of the Federal bureaus, that is, from January 10 to August 23, the convicts were employed on three different roads, namely, the Powers Ferry Road, Hemphill Avenue, and Heards Ferry Road. Only on the Heards Ferry Road, where the work consisted largely of road-machine construction, was the anticipated work completed during the period of observation.

*Powers Ferry Road.*—The work on the road, which occupied the major portion of the time of the men, was done upon a section of the highway 9,900 feet in length, and consisted of grading, guttering, and surfacing with topsoil, together with the construction of incidental drainage structures. The width of right of way cleared was 40 feet. The new road follows approximately the old road bed for a distance of 7,000 feet, the remaining 2,900 feet being in new location. The surrounding country is heavily wooded and very hilly, and owing to right of way conditions and considerations of economy it was impracticable to reduce the maximum grade below 7 per cent, which, however, represented a notable inprovement over the old maximum grade of 12 per cent. The clearing and grubbing amounted to 9 acres. The total amount of excavation was 33,803.6 cubic yards, of which 30,255 cubic yards consisted of residual micaceous clay and 3,548.6 yards of rock, the latter a mica schist. Much of it was fresh and hard, but a small amount was in an advanced state of decomposition. Figure 1 shows a plan and profile of the road as constructed, and the earthwork notes which are shown indicate the character of the construction. The materials of excavation were transported in No. 2½ steel scrapers and dump wagons, the haul varying from a few feet for sidehill construction to a maximum of about 1,000 feet, the average being a little over 600 feet.

Two hundred and eighty-eight linear feet of 15-inch vitrified-clay sewer pipe was placed for drainage purposes, and a concrete bridge consisting of two 14-foot arches was begun at Long Island Creek. Up to the time the Government engineer was withdrawn the excavation for the foundations, consisting of 105 cubic yards of wet sand and clay, had been completed, and 62 cubic yards of concrete had been placed. The stone aggregate was secured from the excavation between stations 63 and 68, and the sand was obtained from the creek and hauled half a mile. Gutters on both sides of the road in all cuts were paved for a width of 3 feet with stone from the excavation, broken by hand to the required size; and 1,500 square yards of the top-soil surfacing had been spread when the experiment was discontinued. The material was obtained from a field near station 2 plus 00 and was hauled an average distance of 1,200 feet.

This work, together with a small amount of miscellaneous work, consisting principally of the moving of a small country store off the right of way, cleaning gutters and repairing washouts, and the Heards Ferry road-machine work constituted the occupation of the convicts from January 10 to July 1, when the Hemphill Avenue construction was begun. Up to August 23, 5 acres of right of way had been cleared and 4,000 cubic yards of earth and 50 cubic yards of rock had been excavated and moved.

*Superintendence and free labor.*—The road work was under the general supervision of the deputy warden who, though he also was responsible for the conduct of the camp, devoted about three-fourths of his time to the construction. He was assisted by two foremen who were in immediate charge of the work and men and whose entire time is properly chargeable to the road work. The wages paid to these officers are given on page 41. Besides these officials the only other citizens employed on the work were a blacksmith, who received $2 per day and board, and a driver, who was paid at the rate of $1.35 per day and board for the time he was actually employed. The latter was employed primarily for the purpose of transporting men and supplies from Atlanta, but a part of his time was devoted to the construction work.

*Teams.*—From January to August an average of 12.92 pairs of the county's mules were kept in the stable attached to the camp. They were valued at $600 per pair and it is estimated that they depreciated at the rate of 10 per cent per year. Harness cost $40.50 per double team, and it is estimated that it depreciated at the rate of 25 per cent per year. Actual records of the cost of feed and bedding show that this item amounted to $1.057 per double team per calendar day. No account is taken in this connection of the cost of shoeing, but proper allowance is made for it in connection with the cost of maintaining the blacksmith shop. Based upon the above figures the summarized cost of one team per calendar day is as follows:

| | |
|---|---|
| Interest on cost of team at 6 per cent per year | $0.098 |
| Depreciation of a team at 10 per cent per year | .164 |
| Interest on cost of harness at 6 per cent per year | .007 |
| Depreciation of harness at 25 per cent per year | .027 |
| Feed and bedding | 1.057 |
| Total cost per calendar day | 1.353 |

The records of the camp show that up to August 10 maintenance was provided for 2,351 team days, and the following table shows the number of team days actually employed and lost:

| | |
|---|---|
| Number of team days employed | 1,661.0 |
| Number of team days idle | 244.5 |
| Number of team days lost by sickness | 77.5 |
| Number of team days lost by Sundays and holidays | 368.0 |
| Total team days to Aug. 10 | 2,351.0 |

It is evident, therefore, that the team days actually employed formed only 70.7 per cent of the total number for which maintenance was provided, and the cost of a double team and harness per actual working day therefore was

$$1.353 \div 0.707 = \$1.91.$$

All work teams were driven by convicts except that part of the time of the one free driver which was spent on the road work.

*Construction equipment.*—Table 34 is a complete list of the construction equipment used in the course of the experiment.

TABLE 34.—*Construction equipment.*

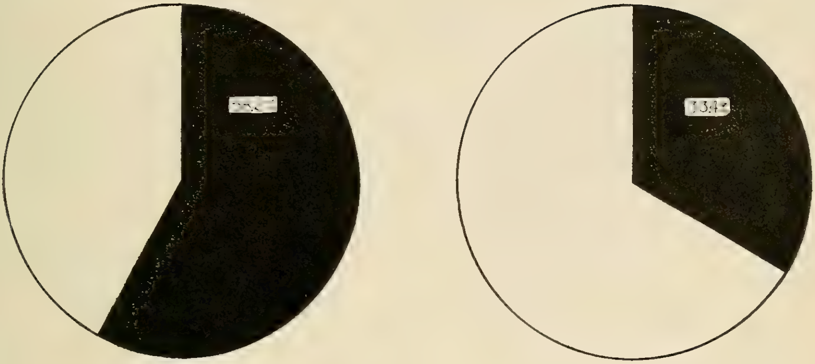
| Item. | Number. | Value. | Item. | Number. | Value. |
|---|---|---|---|---|---|
| Two-horse wagons | 4 | $160 | Mattocks | 27 | $8 |
| One-horse wagon | 1 | 30 | Wheelbarrows | 4 | 6 |
| No. 2½ wheelers | 8 | 320 | Blasting machine | 1 | 15 |
| Small road machine | 1 | 75 | Picks | 24 | 24 |
| Steam drill and accessories | 1 | 300 | 39-pound stone hammers | 8 | 6 |
| Portable boiler | 1 | 350 | Miscellaneous repairs, steel, leather, horseshoes, etc | | 374 |
| Blacksmith outfit and small tools | 1 | 100 | Stables, shop, etc | | 150 |
| Grading plows | 2 | 50 | | | |
| Axes | 24 | 15 | Total | | 2,008 |
| Short-handled shovels | 36 | 25 | | | |

The customary allowances have been made for depreciation of this equipment and the costs have been properly charged as "equipment" to each item of construction in Table 35.

TABLE 35.—*Summary of cost of construction.*

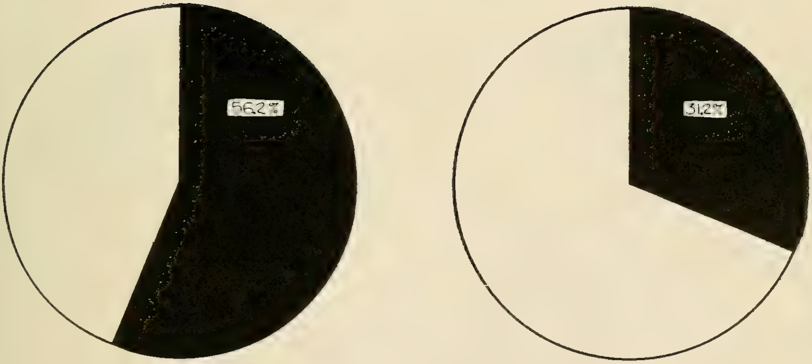
POWERS FERRY ROAD.

| | Cost. | Per cent. |
|---|---|---|
| Earth excavation: | | |
| Supervision | $442.65 | 7.1 |
| Teams | 2,462.85 | 39.5 |
| Materials | 314.19 | 5.0 |
| Equipment | 334.95 | 5.5 |
| General expense | 356.91 | 5.7 |
| Convict labor | 2,325.26 | 37.2 |
| Total | 6,236.81 | 100.0 |
| Quantity of excavation, 30,255 cubic yards. | | |
| Cost per cubic yard, 20.6 cents. | | |
| Rock excavation: | | |
| Supervision | 193.57 | 10.0 |
| Teams | 296.60 | 15.5 |
| Materials | 376.79 | 19.5 |
| Equipment | 172.00 | 8.9 |
| General expense | 88.00 | 4.6 |
| Convict labor | 800.70 | 41.5 |
| Total | 1,927.66 | 100.0 |
| Quantity of excavation, 3,548.6 cubic yards. | | |
| Cost per cubic yard, 54.3 cents. | | |
| Clearing and grubbing: | | |
| Supervision | 86.87 | 14.5 |
| Teams | 27.07 | 4.3 |
| Materials | 98.62 | 16.0 |
| Equipment | 8.90 | 1.4 |
| General expense | 32.30 | 5.2 |
| Convict labor | 360.41 | 58.6 |
| Total | 614.17 | 100.0 |
| Area cleared and grubbed, 9 acres. | | |
| Cost per acre, $68.24. | | |
| 15-inch vitrified-clay pipe: | | |
| Supervision | 2.04 | 1.6 |
| Materials | 109.68 | 86.5 |
| Equipment | .07 | ..... |
| General expense | 1.10 | .9 |
| Convict labor | 14.05 | 11.0 |
| Total | 126.94 | 100.0 |
| Amount of pipe laid, 288 linear feet. | | |
| Cost per linear foot, 44 cents. | | |
| Concrete masonry: | | |
| Supervision | 30.11 | 10.1 |
| Teams | 7.64 | 2.5 |
| Materials | 186.70 | 62.4 |
| Equipment | 1.09 | .4 |
| General expense | 7.10 | 2.4 |
| Convict labor | 66.38 | 22.2 |
| Total | 299.02 | 100.0 |
| Amount of masonry, 62 cubic yards. | | |
| Cost per cubic yard, $4.83. | | |



PAVING GUTTERS

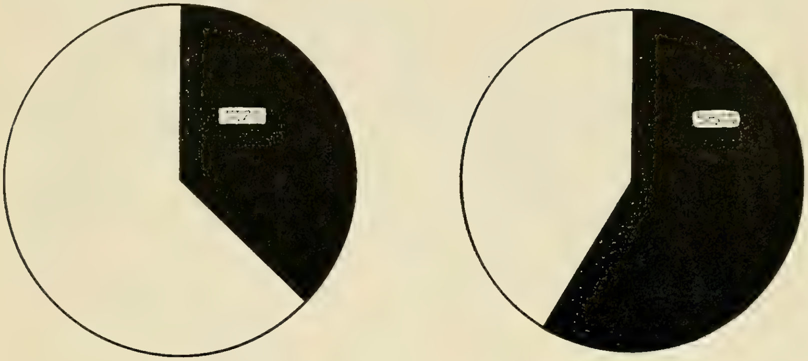
TOP SOILING



WET EXCAVATION

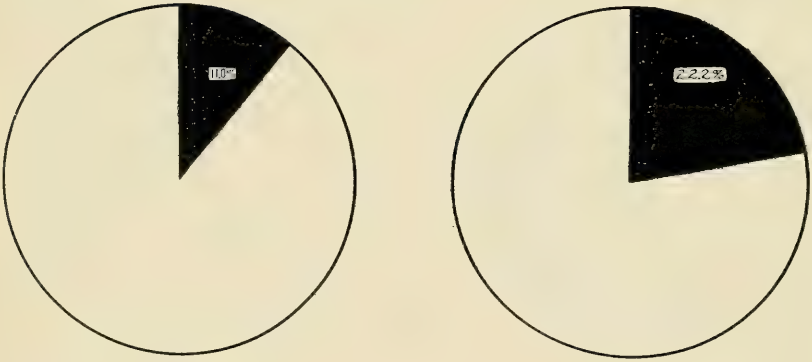
DROP INLETS

DIAGRAMS SHOWING COMPARISON OF COST OF CONVICT LABOR WITH TOTAL COST OF WORK.



EARTH EXCAVATION

ROCK EXCAVATION



VITRIFIED PIPE

CONCRETE MASONRY

DIAGRAMS SHOWING COMPARISON OF COST OF CONVICT LABOR WITH TOTAL COST OF WORK.

| Wet excavation for bridges: | Cost. | Per cent. |
|---|---|---|
| Supervision | $16.28 | 22.5 |
| Teams | 10.55 | 14.5 |
| Equipment | .42 | .6 |
| General expense | 4.60 | 6.2 |
| Convict labor | 40.61 | 56.2 |
| Total | 72.46 | 100.0 |

Quantity of excavation, 105 cubic yards.
Cost per cubic yard, 67 cents.

| Construction of drop inlets: | | |
|---|---|---|
| Supervision | 21.73 | 13.1 |
| Teams | 10.86 | 6.5 |
| Materials | 75.95 | 45.7 |
| Equipment | .04 | ..... |
| General expense | 5.78 | 3.5 |
| Convict labor | 51.92 | 31.2 |
| Total | 166.28 | 100.0 |

Quantity of masonry, 51.6 cubic yards.
Cost per cubic yard, $3.22.

| Gutter pavement: | | |
|---|---|---|
| Suvervision | 112.35 | 13.1 |
| Teams | 187.97 | 21.8 |
| Equipment | 4.71 | .5 |
| General expense | 54.59 | 6.4 |
| Convict labor | 499.78 | 58.2 |
| Total | 859.40 | 100.0 |

Area of gutter pavement, 4,747 square yards.
Cost per square yard, 18.1 cents.

| Top-soil surface: | | |
|---|---|---|
| Supervision | 7.43 | 10.7 |
| Teams | 34.38 | 49.0 |
| Equipment | .38 | .5 |
| General expense | 4.45 | 6.4 |
| Convict labor | 23.43 | 33.4 |
| Total | 70.07 | 100.0 |

Area of surface, 1,500 square yards.
Cost per square yard, 4.7 cents.

| Miscellaneous work: | | |
|---|---|---|
| Total cost | | $270 |

### RECAPITULATION.

Cost of Power's Ferry Road Work.

| | |
|---|---|
| Earth excavation | $6,236.81 |
| Rock excavation | 1,927.66 |
| Clearing and grubbing | 614.17 |
| Culvert pipe in place | 126.94 |
| Concrete masonry | 299.02 |
| Excavation for bridge | 72.46 |
| Drop inlets | 166.28 |
| Gutter pavements | 859.40 |
| Top-soil surface | 70.07 |
| Miscellaneous work | 270.00 |
| Total cost | 10,642.81 |

### HEMPHILL AVENUE.

| | Cost. | Per cent. |
|---|---|---|
| Earth excavation: | | |
| Supervision | $37.90 | 7.3 |
| Teams | 226.67 | 43.6 |
| Equipment | 28.55 | 5.5 |
| General expense | 31.40 | 6.0 |
| Convict labor | 195.23 | 37.6 |
| Total | 519.75 | 100.0 |
| Quantity of excavation, 4,000 cubic yards. | | |
| Cost per cubic yard, 13 cents. | | |
| Rock excavation: | | |
| Supervision | 1.60 | 5.6 |
| Teams | 3.82 | 13.5 |
| Materials | 13.35 | 46.8 |
| Equipment | 1.72 | 6.0 |
| General expense | .93 | 3.4 |
| Convict labor | 7.02 | 24.7 |
| Total | 28.44 | 100.0 |
| Quantity of excavation, 50 cubic yards. | | |
| Cost per cubic yard, 56.9 cents. | | |
| Clearing and grubbing: | | |
| Supervision | 11.61 | 10.8 |
| Teams | 20.41 | 19.0 |
| Materials | 3.86 | 3.6 |
| Equipment | 1.80 | 1.7 |
| General expense | 6.53 | 6.1 |
| Convict labor | 63.26 | 58.8 |
| Total | 107.47 | 100.0 |
| Area cleared and grubbed, 5 acres. | | |
| Cost per acre, $21.49. | | |
| 15-inch vitrified-clay pipe culverts: | | |
| Materials | 11.52 | 73.4 |
| General expense | .26 | 1.7 |
| Convict labor | 3.90 | 24.9 |
| Total | 15.68 | 100.0 |
| Amount of pipe laid, 32 feet. | | |
| Cost per linear foot, 49 cents. | | |

### RECAPITULATION.

Cost of Hemphill Avenue work.

| | |
|---|---|
| Earth excavation | $519.75 |
| Rock excavation | 28.44 |
| Clearing and grubbing | 107.47 |
| Culvert pipe in place | 15.68 |
| Total cost | 671.34 |

### HEARDS FERRY ROAD.

| | Cost. | Per cent. |
|---|---|---|
| Clearing and grubbing: | | |
| Supervision | $7.70 | 8.3 |
| Teams | 20.71 | 22.0 |
| Materials | 20.64 | 21.9 |
| Equipment | 1.27 | 1.4 |
| General expense | 4.64 | 4.9 |
| Convict labor | 39.05 | 41.5 |
| Total | 94.01 | 100.0 |
| Area cleared and grubbed, 2 acres. | | |
| Cost per acre, $47. | | |
| Earth excavation (by road machine): | | |
| Supervision | 7.24 | 6.8 |
| Teams | 42.02 | 39.8 |
| Equipment | 12.99 | 12.3 |
| General expense | 5.92 | 5.6 |
| Convict labor | 37.49 | 35.5 |
| Total | 105.66 | 100.0 |
| Quantity of excavation, 1,667 cubic yards. | | |
| Cost per cubic yard, 6½ cents. | | |

### RECAPITULATION.

Cost of Heard's Ferry Road work.

| | |
|---|---|
| Clearing and grubbing | $94.01 |
| Earth excavation | 105.66 |
| Total | 199.67 |

In these tables the item "general expense" includes the wages and board of foremen on Sundays and holidays, the wages and board of the blacksmith, and the wages and board of the free driver when he was employed on work of a general nature.

The total amount of this expense was $632.02, made up as follows:

### GENERAL EXPENSE.

| | |
|---|---|
| Supervision | $279.35 |
| Blacksmith | 333.66 |
| Free driver | 19.01 |
| Total | 632.02 |

As the only saving which can be made by the use of convict labor must be derived from the labor itself, it follows that the kind of work best adapted to the employment of convicts is that in which the labor cost forms the largest part of the whole cost. To indicate the differences between the various kinds of work performed by the experimental convicts, the column headed "per cent" has been added to the cost tables, and the diagrams shown in Plates VIII and IX have been prepared. They indicate very clearly that, of the various kinds of work performed, clearing and grubbing and excavation are best adapted to the employment of prisoners, and that such work as culvert and bridge construction is to be avoided whenever possible. It should be noted that the exceptionally high percentage in the case of gutter pavements represents only an apparent advantage in this kind of work, as no charge is made for material which ordinarily would form a large part of the cost. In the Atlanta construction the rock was obtained from the excavation without cost other than that of hauling and breaking to size.

The economy resulting from the employment of the convicts in this work and the high degree of efficiency with which they were maintained and organized are proved by the low unit costs of the work, as shown by the tables of costs. That the efficiency of the experimental camp workers was distinctly above that of the other county squads was noted by all who observed them at the Lakewood fair grounds, where they worked side by side with representatives of other camps. Finally, the fact that such costs could be obtained under the severe conditions surrounding this experiment affords the most convincing proof of the soundness of the methods of organization, discipline, and convict maintenance employed.

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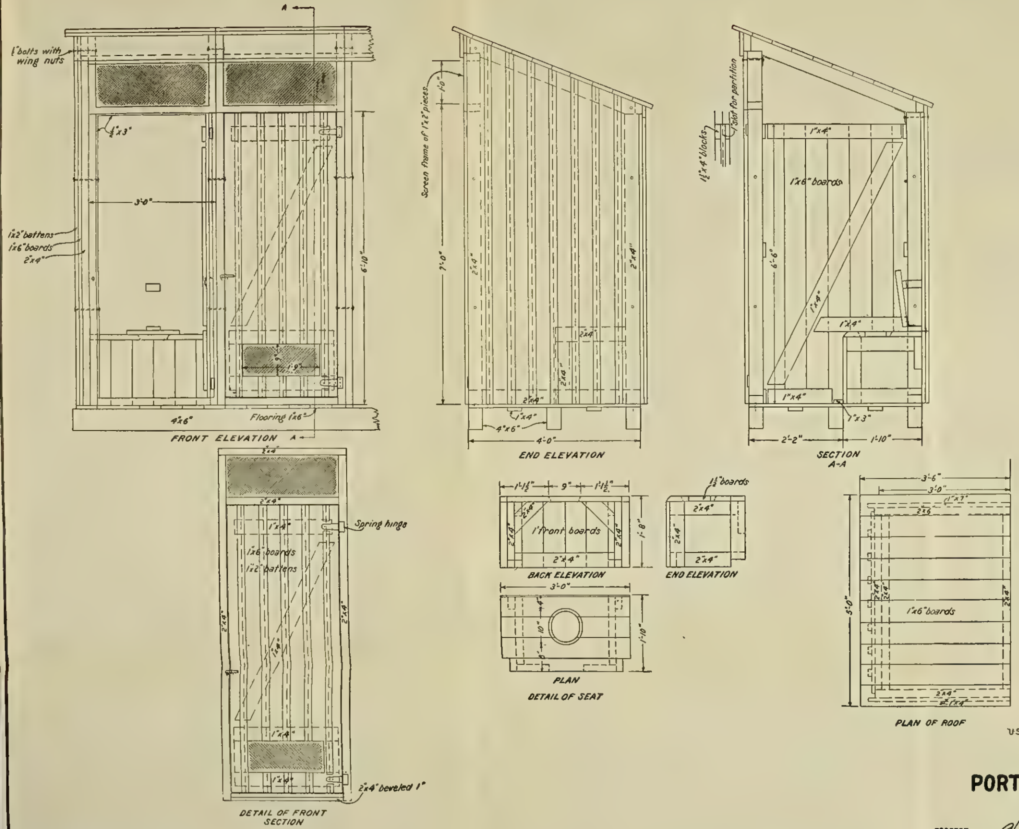


U.S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

## DETAILS

# PORTABLE FLYPROOF PRIVY

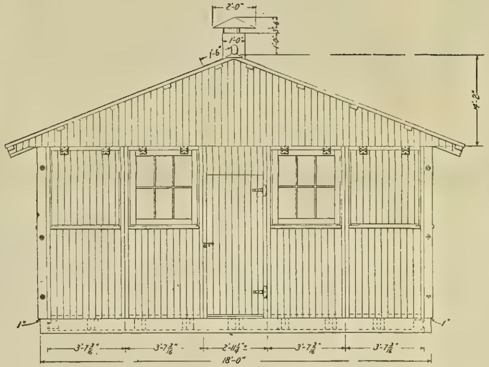
SCALE, 1" = 1'-0"

CORRECT H. S. Fairbank HIGHWAY ENGINEER

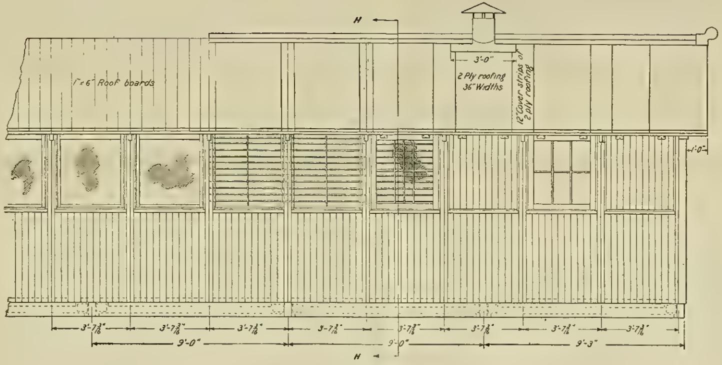
APPROVED J. E. Pennybacker CHIEF, ROAD ECONOMICS

E-56

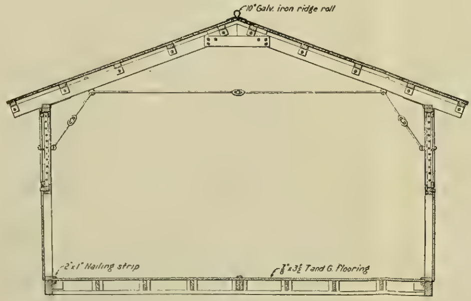
DESIGNED BY H. S. Fairbank DATE 2-15-16
TRACED BY G. C. Dunn DATE 2-19-16
CHECKED BY H. S. Fairbank DATE 2-18-16



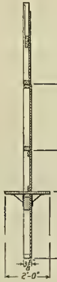
END VIEW



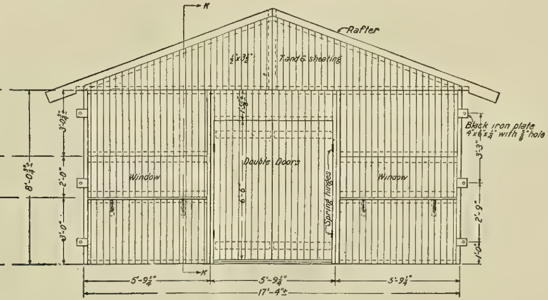
SIDE VIEW



SECTION H-H



SECTION K-K



KITCHEN-DINING ROOM PARTITION

U.S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

## GENERAL VIEWS

# PORTABLE CONVICT CAMP BUILDING

SCALE, 1/2" = 1'-0"

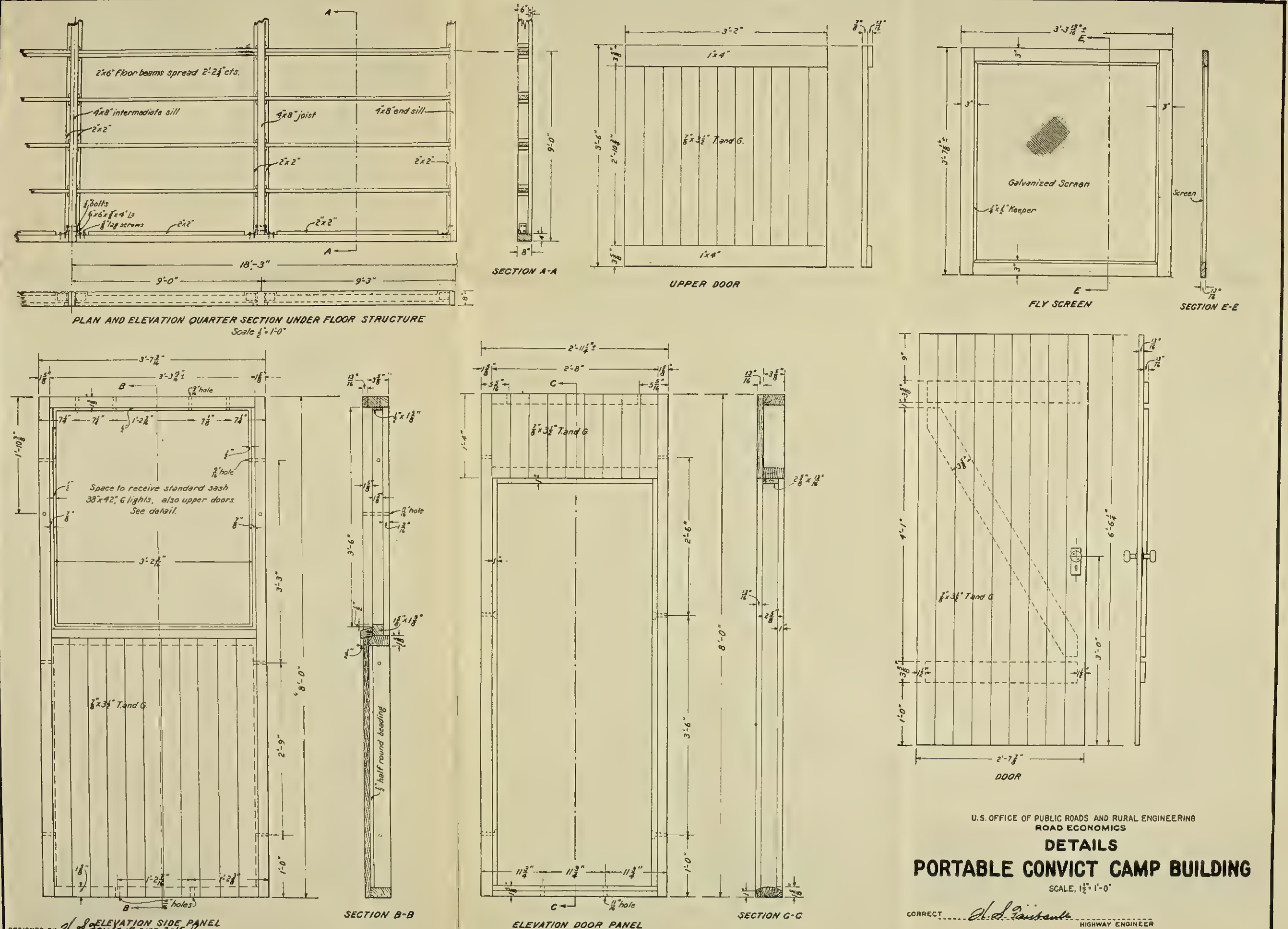
CORRECT H. S. Fairbank HIGHWAY ENGINEER

APPROVED J. E. Pennybacker CHIEF, ROAD ECONOMICS

E-57

DESIGNED BY H. S. Fairbank DATE 2-15-16
TRACED BY O. P. [illegible] DATE [illegible]
CHECKED BY H. S. Fairbank DATE 3-24-16

5847°—18—Bull. 583. (To face page 64.) No. 1



U. S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

**DETAILS**

**PORTABLE CONVICT CAMP BUILDING**

SCALE, 1½"= 1'-0"

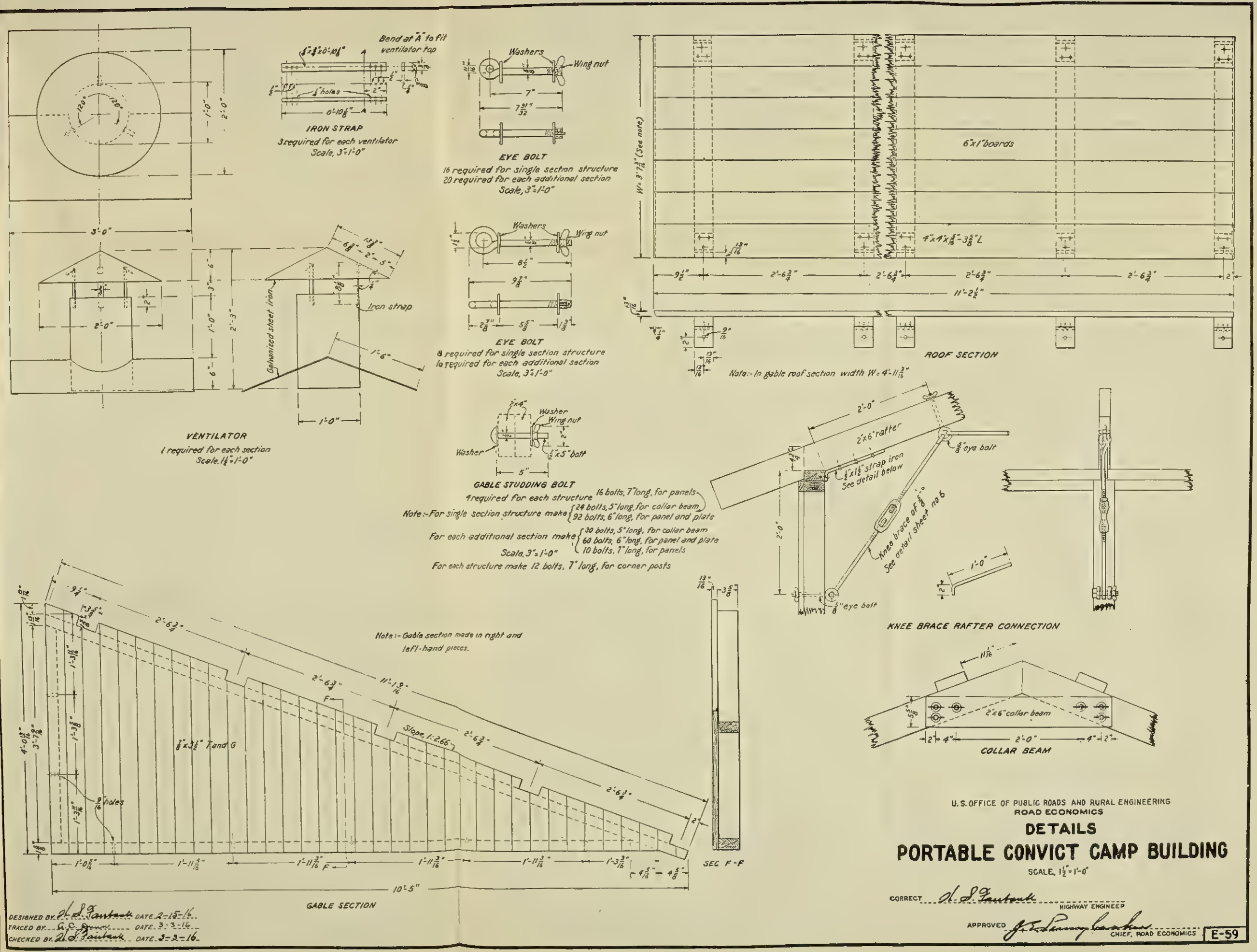
CORRECT H. S. Fairbank HIGHWAY ENGINEER

APPROVED J. E. Pennybacker CHIEF, ROAD ECONOMICS

E-58

DESIGNED BY H. S. Fairbank DATE 2-15-16
TRACED BY G. C. Dunn DATE 2-29-16
CHECKED BY H. S. Fairbank DATE 2-29-16

5847°—18—Bull. 583. (To face page 64.) No. 2



**IRON STRAP**

3 required for each ventilator
Scale, 3"=1'-0"

**EYE BOLT**

16 required for single section structure
20 required for each additional section
Scale, 3"=1'-0"

**EYE BOLT**

8 required for single section structure
10 required for each additional section
Scale, 3"=1'-0"

**VENTILATOR**

1 required for each section
Scale, 1$\frac{1}{2}$"=1'-0"

**GABLE STUDDING BOLT**

4 required for each structure

Note:-For single section structure make
- 16 bolts, 7" long, for panels
- 24 bolts, 5" long, for collar beam
- 92 bolts, 6" long, for panel and plate

For each additional section make
- 30 bolts, 5" long, for collar beam
- 60 bolts, 6" long, for panel and plate
- 10 bolts, 7" long, for panels

Scale, 3"=1'-0"

For each structure make 12 bolts, 7" long, for corner posts

**ROOF SECTION**

Note:-In gable roof section width W=4'-11$\frac{3}{4}$"

**KNEE BRACE RAFTER CONNECTION**

**COLLAR BEAM**

Note:-Gable section made in right and left-hand pieces.

**GABLE SECTION**

**SEC F-F**

U.S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

## DETAILS

## PORTABLE CONVICT CAMP BUILDING

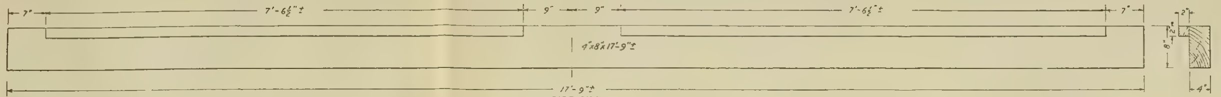
SCALE, 1$\frac{1}{2}$"=1'-0"

CORRECT H. S. Fairbank HIGHWAY ENGINEER

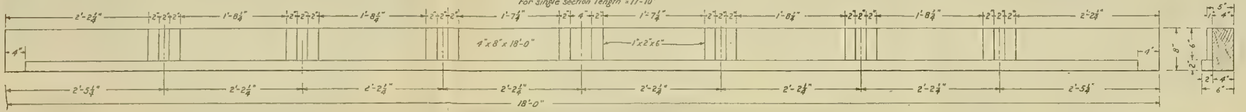
APPROVED J. E. Pennybacker CHIEF, ROAD ECONOMICS

E-59

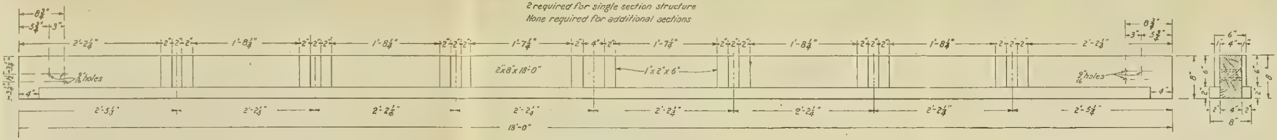
DESIGNED BY H. S. Fairbank DATE 2-15-16
TRACED BY A. C. ... DATE 3-3-16
CHECKED BY H. S. Fairbank DATE 3-3-16



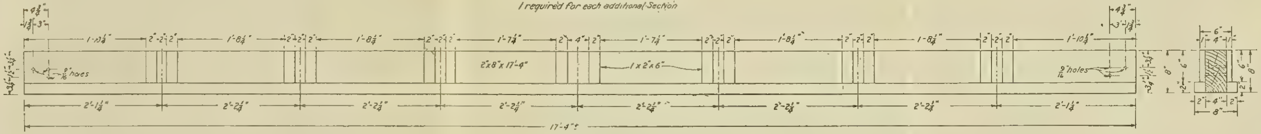
SIDE SILL
2 required for each section
For single section length = 17'-10"



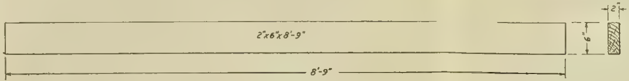
END SILL
2 required for single section structure
None required for additional sections



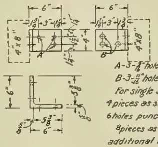
INTERMEDIATE SILL
None required for single section structure
1 required for each additional Section



JOIST
1 required for each section

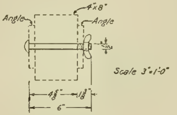


FLOOR BEAMS
16 required for each section
For interior of continued sections, length = 8'-8"

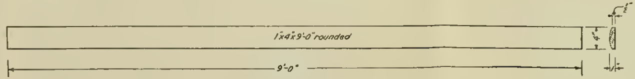


A-3-9/16" holes for ½" bolts.
B-3-11/16" holes for ⅝" lag screws.
For single section structure make 4 pieces as shown and 4 pieces with all 6 holes punched as B
8 pieces as shown required for each additional section.

CONNECTION ANGLE
(6"x6"x4"x⅝" steel)



BOLT
(For connection angle)
6 required for single section structure
12 required for each additional section



FLOOR STRIP
2 required for each section

U. S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

## FLOOR DETAILS
## PORTABLE CONVICT CAMP BUILDING

SCALE, 1½" = 1'-0"

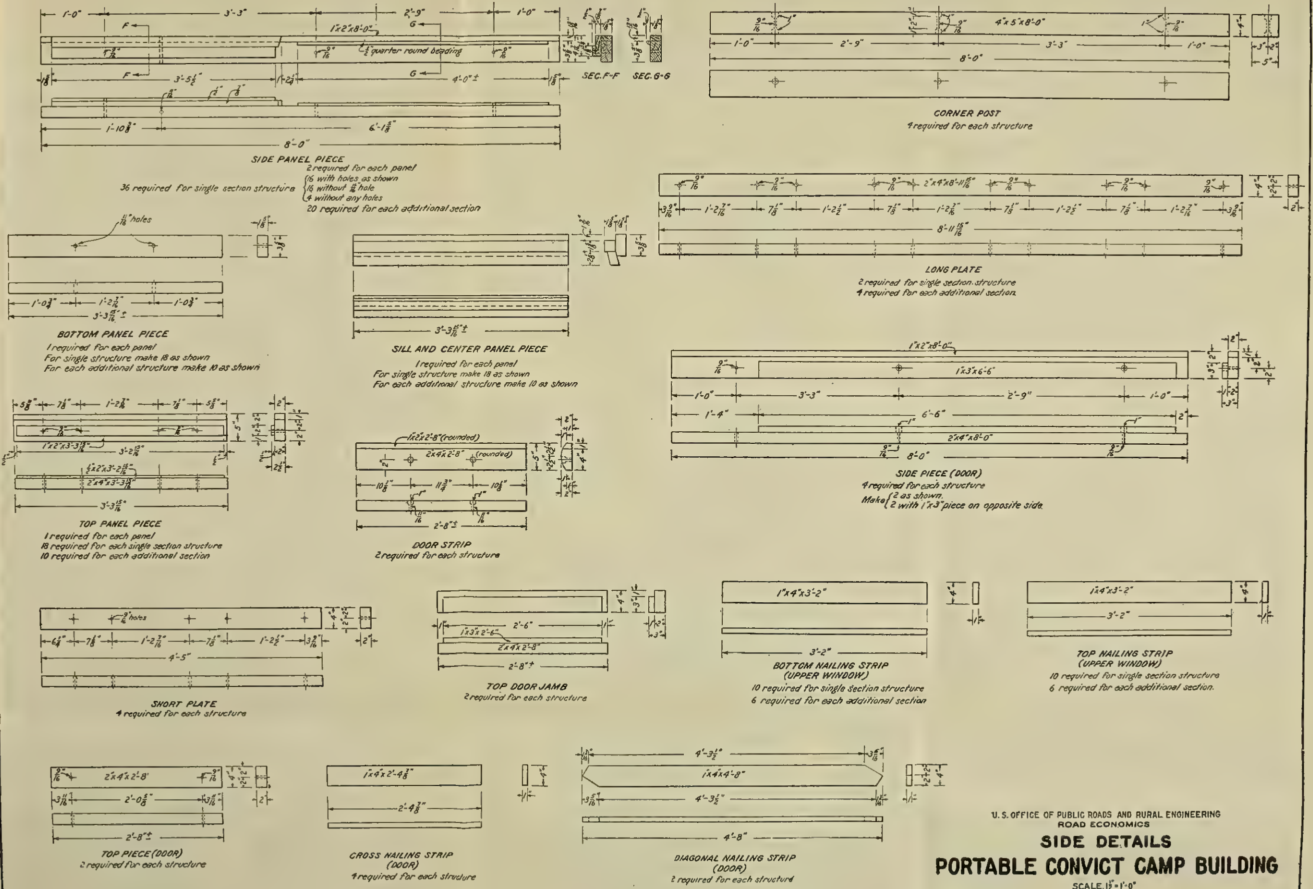
CORRECT H. S. Fairbank
HIGHWAY ENGINEER

APPROVED J. E. Pennybacker
CHIEF, ROAD ECONOMICS

E-60

DESIGNED BY H. S. Fairbank DATE 2-15-16
TRACED BY G. C. ______ DATE 3-4-16
CHECKED BY H. S. Fairbank DATE 3-4-16

5847°—18—Bull. 583. (To face page 64.) No. 4



SIDE PANEL PIECE
2 required for each panel
36 required for single section structure {16 with holes as shown / 16 without 11/16" hole / 4 without any holes
20 required for each additional section

CORNER POST
4 required for each structure

LONG PLATE
2 required for single section structure
4 required for each additional section

BOTTOM PANEL PIECE
1 required for each panel
For single structure make 18 as shown
For each additional structure make 10 as shown

SILL AND CENTER PANEL PIECE
1 required for each panel
For single structure make 18 as shown
For each additional structure make 10 as shown

SIDE PIECE (DOOR)
4 required for each structure
Make {2 as shown. / 2 with 1"x3" piece on opposite side

TOP PANEL PIECE
1 required for each panel
18 required for each single section structure
10 required for each additional section

DOOR STRIP
2 required for each structure

SHORT PLATE
4 required for each structure

TOP DOOR JAMB
2 required for each structure

BOTTOM NAILING STRIP
(UPPER WINDOW)
10 required for single section structure
6 required for each additional section

TOP NAILING STRIP
(UPPER WINDOW)
10 required for single section structure
6 required for each additional section.

TOP PIECE (DOOR)
2 required for each structure

CROSS NAILING STRIP
(DOOR)
4 required for each structure

DIAGONAL NAILING STRIP
(DOOR)
2 required for each structure

U. S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

## SIDE DETAILS

# PORTABLE CONVICT CAMP BUILDING

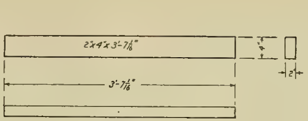
SCALE, 1½" = 1'-0"

CORRECT D. S. Fairbank
HIGHWAY ENGINEER

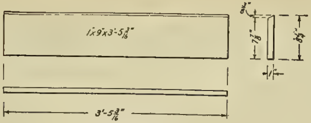
APPROVED J. E. Pennybacker
CHIEF, ROAD ECONOMICS

E-61

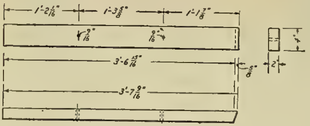
DESIGNED BY D. S. Fairbank DATE 3-4-16
TRACED BY G. C. Dunn DATE 3-9-16
CHECKED BY D. S. Fairbank DATE 3-9-16



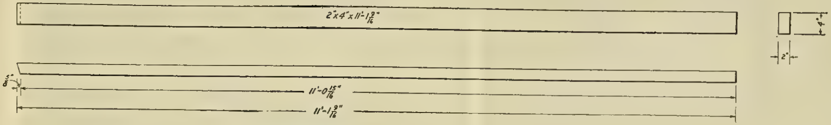
PURLIN
50 required for each section



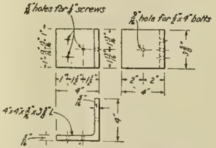
FILLER STRIP (EAVES)
10 required for each section



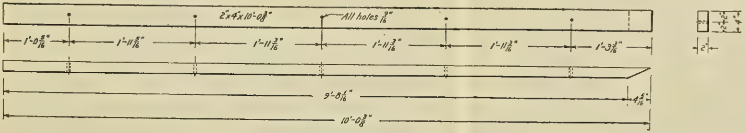
GABLE END STUDDING
4 required for each structure



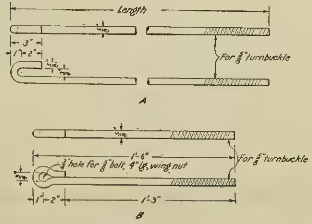
GABLE END RAFTER
4 required for each structure



CONNECTING ANGLE (FOR PURLIN)
80 required for single section structure
100 required for each additional section
Scale, 3"=1'-0"



BOTTOM PLATE (GABLE END)
4 required for each structure



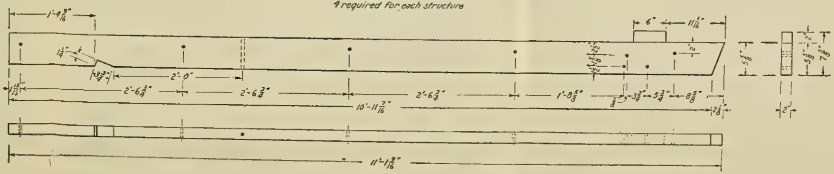
BRACE RODS

For single section structure { 8 required as "A", 6'-7 1/2" long.
8 " " "A" 1'-6" "
8 " " "B" 1'-6" "

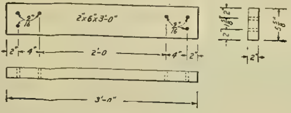
For each additional section { 10 " " "A" 6'-7 1/2" " .
10 " " "A" 1'-6" " .
10 " " "B" 1'-6" " .

Make half with right hand threads
" " " left " "

Scale, 3"=1'-0"



RAFTER
8 required for single section structure
10 required for each additional section



COLLAR BEAM
4 required for single section structure
5 required for each additional section

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ROAD ECONOMICS

## ROOF DETAILS

# PORTABLE CONVICT CAMP BUILDING

SCALE, 1 1/2"=1'-0"

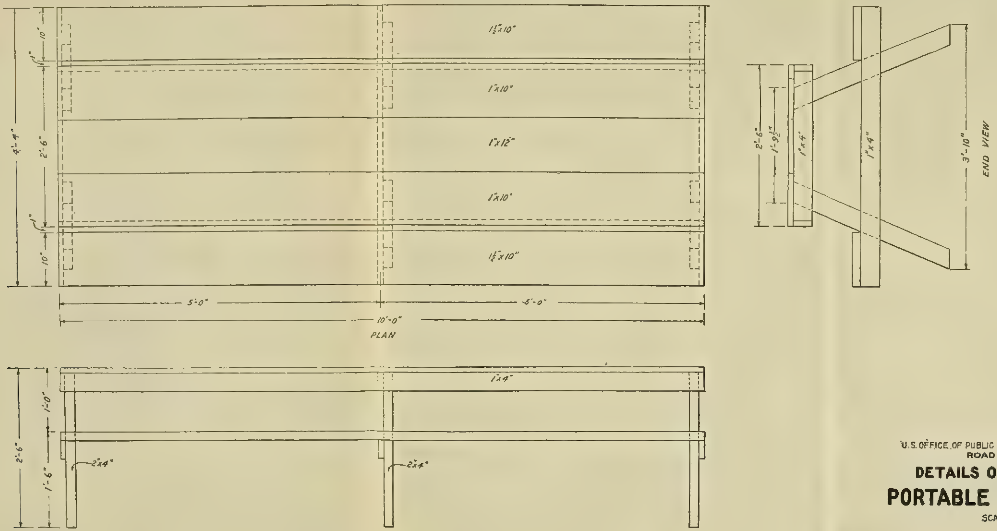
CORRECT H. S. Fairbank
HIGHWAY ENGINEER

APPROVED J. E. Pennybacker
CHIEF, ROAD ECONOMICS

E-62

DESIGNED BY. H. S. Fairbank DATE 2-15-16
TRACED BY. G. C. DATE 3-10-16
CHECKED BY. H. S. Fairbank DATE 3-10-16

5847°—18—Bull. 583. (To face page 64.) No. 6



U.S. OFFICE OF PUBLIC ROADS AND RURAL ENGINEERING
ROAD ECONOMICS

## DETAILS OF MESS TABLE

## PORTABLE CONVICT CAMP

SCALE-1½"=1'-0"

CORRECT H. S. Fairbank
HIGHWAY ENGINEER

APPROVED J. E. Pennybacker
CHIEF, ROAD ECONOMICS

F-6

ESIGNED BY. H. S. Fairbank DATE 2-15-16.
RACED BY. G. C. DATE 3-4-16
ECKED BY. H. S. Fairbank DATE 3-4-16

5847°—18—Bull. 583. (To face page 64.) No. 8

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 584

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

Washington, D. C. ▼ October 13, 1917

# THE CONTROL OF HOG CHOLERA, WITH A DISCUSSION OF THE RESULTS OF FIELD EXPERIMENTS.

By A. D. Melvin, *Chief of the Bureau of Animal Industry*, and M. Dorset, *Chief of the Biochemic Division.*

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## NATURE AND PREVALENCE OF HOG CHOLERA.

During the past three decades hog cholera has probably caused greater loss to the farming communities of the United States than any other animal plague. Originally appearing in the States of the Atlantic seaboard and of the Ohio Valley, it has gradually spread over the entire country, until at the present time the disease may be said to exist in endemic form in all parts of the United States. It is not always equally prevalent, but, on the contrary, at intervals assumes the character of a severe epizootic, sweeping over the entire country, only later to subside for a period of years, after which it again increases in prevalence. This characteristic of periodic prevalence is well illustrated by the accompanying chart (fig. 1) prepared from statistics collected by the Bureau of Crop Estimates of the United States Department of Agriculture.

For many years it has been known that hog cholera is an infectious disease, produced by a specific microorganism which develops in the bodies of affected hogs. Only swine are susceptible. The existence of the infectious agent in the bodies of infected hogs may be readily demonstrated, but all efforts to isolate and grow the virus in laboratories have resulted in failure. The microorganism in this respect resembles those which cause foot-and-mouth disease of animals and the very fatal yellow fever of human beings. The fact that the precise nature of the microorganism causing hog cholera has not been determined does not seem, however, to be an insuperable barrier to successful methods of control, for it is recognized that the virus is propagated exclusively in the bodies of infected hogs and from them conveyed to others. Knowing this, at first thought the problem of control would seem to be comparatively simple. Quarantine or slaughter of infected herds, supplemented by careful disinfection, are clearly indicated as effective measures. But these are drastic measures, and before their adoption the cost of their enforcement must be weighed against the chances of success and the relative advantages of other modes of procedure.

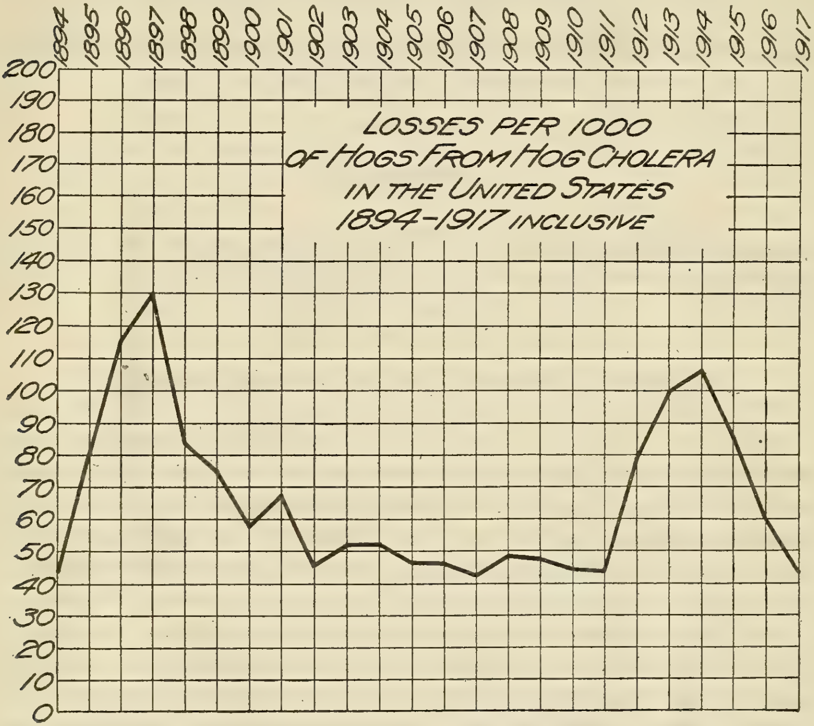

FIG. 1.—Losses from hog cholera in the United States, years ending March 31, 1894–1917, inclusive.

In Canada there are several million hogs, but cholera has never been widespread there. When it has occurred the veterinary authorities have promptly checked the disease by quarantining the farm, slaughtering all hogs, disinfecting the premises, and prohibiting the restocking of the farm for a period of three months. In Canada, then, we apparently have an instance of the successful control of cholera by quarantine, disinfection, and slaughter. In Great Britain, however, the case is different. There the disease is as widespread as it is in the United States. There, as in Canada, for many years the policy of quarantine, slaughter, and disinfection has been followed, but not with the same success. Hog cholera still exists and at certain times shows the same tendency to increase that is observed in the United States, where no country-wide systematic effort at control has ever been attempted. A number of factors have no doubt operated to prevent success in Great Britain by methods which have seemed to be effective in Canada. Among the most important of these may be mentioned a large number of hogs in proportion to area, wide dissemination of the disease, and numerous avenues of communication and traffic through which the disease may be spread.

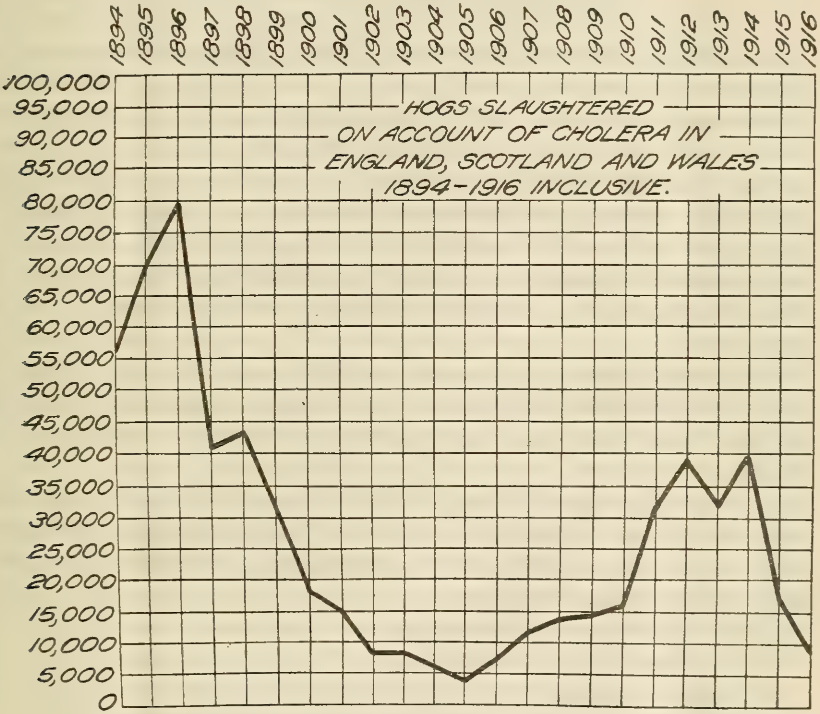

FIG. 2.—Course of hog cholera in Great Britain, 1894 to 1916.

The course of the disease in Great Britain during the past 23 years is indicated in figure 2.

With the experience of Great Britain as an example, we in the United States with widespread disease, great numbers of hogs, and many channels of communication to serve as conveyors of infection could certainly not enter upon a campaign of eradication by quarantine and slaughter with any assurance of success, despite the fact that at first glance the problem appears to be simple. Then, too, the cost must be considered. An army of thousands of employees would be required, millions of dollars would be needed for the reimbursement of owners, and the interference with the hog industry of the country would be so great that any such campaign for the eradication of hog cholera instead of proving a boon might come to be regarded by the hog raisers of the country as a calamity.

With the above ideas in mind, the United States Bureau of Animal Industry has given much study to the development of some practical working plan for controlling losses from hog cholera. With this object in view, laboratory researches and field experiments have been continuously prosecuted for a number of years.

## THE SERUM METHOD OF CONTROL.

As early as 1904 the Bureau of Animal Industry announced the discovery of a serum which would protect hogs against cholera. Work was continued, and in 1908 representatives of the various States were made acquainted with the methods of producing this serum, with the hope that its widespread application might serve to accomplish what it seemed unwise to undertake through methods of rigid quarantine and slaughter. This anti-hog-cholera serum gradually came into general use, and the original statements as to its efficaciousness were thoroughly substantiated by successful use in practice.

The development of this serum afforded a new weapon for attacking hog cholera and gave rise to the hope that it might be employed at least to reduce losses and perhaps ultimately to eradicate the disease.

In 1908 a plan for the employment of serum in control work was suggested by one of the writers (Melvin) in an article in the Twenty-fifth Annual Report of the Bureau of Animal Industry. This plan embodied the following features:

1. Division of a State into districts.
2. An adequate supply of serum.
3. Prompt notification of outbreaks.
4. Quarantine and disinfection of infected premises.
5. Prompt treatment of infected herds with serum.
6. Immunization of neighboring herds by inoculation with serum and virus (simultaneous inoculation).

This plan seemed to possess many advantages over the method of quarantine and slaughter. If properly carried out, a large proportion of each infected herd should be saved and become exceptionally valuable on account of the immunity which would be established. The business of the farmer would not be seriously interfered with, as all new stock could be immunized before being brought upon the infected premises, while the immunization of neighboring herds probably would lessen greatly the chances of spread. All things considered, then, this plan seemed to be one that would enlist the cooperation of farmers and at the same time do much toward reducing the losses from the disease.

On July 1, 1913, the Congress of the United States appropriated the sum of $75,000 to be used for the purpose of "demonstrating the best method of preventing and eradicating hog cholera," and later, on February 23, 1914, supplemented this with an additional appropriation to permit work on a much larger scale. With these funds extensive field experiments have been carried on, and it is the purpose of this paper to discuss the results of these experiments, both with respect to their bearing upon the broad questions of control and upon certain important, though minor, questions that are involved.

## FIELD EXPERIMENTS LOOKING TO THE CONTROL OF HOG CHOLERA.

As stated above, the first appropriation for field work became available on July 1, 1913, and the work itself was begun at that time. The plan was to try out in several small areas the procedure suggested and outlined in the preceding section. A single county was adopted as the unit area for the experiments, and during the first year work was carried on in three counties, namely, Dallas County, Iowa, Montgomery County, Ind., and Pettis County, Mo. Later, in the spring of 1914, when more money had become available, other counties in other States were added, so that in the summer of 1914 active work was being carried on in 14 counties in 12 different States.

In each county the United States Department of Agriculture placed three veterinary inspectors and one clerk, previous arrangements having been made with the State agricultural college and with the State veterinarian or live-stock sanitary board for cooperation in educational work on the one hand and in the enforcement of the necessary sanitary regulations on the other.

At the beginning, in each county steps were taken with the aid of the State agricultural college to inform farmers of the objects sought, of the characteristics of the disease and channels which serve to convey it, and of the importance of promptly reporting outbreaks. A census of hogs and of losses from diseases was taken, and the existing centers of infection were located as far as possible. To obtain the cooperation of the farmers, which is an essential to success in work of this nature, organizations of farmers were formed in each township, consisting of one leader and eight district representatives. Each of the district representatives was charged with the duty of reporting the occurrence of disease among hogs in his district to the federal inspector in charge. The State veterinarian was to have all local stockyards and loading places cleaned and disinfected and to cooperate with Federal officials by instructing owners of infected premises concerning methods of disinfection, and by supervising such operations. The Federal inspectors, besides participating in the sanitary work and the work of organization, were particularly charged with the administration of serum to infected herds and the immunization of neighboring herds. To avoid antagonism on the part of farmers, a partial quarantine only of infected premises was enforced.

It will thus be seen that work was done along three principal lines, as follows:

1. Organization and education.
2. Sanitation.
3. Serum treatment.

In practically all of the counties hog cholera was widespread when the work was begun, and it was soon found that many difficulties lay in the way of carrying out the plan proposed. In the first place the great prevalence of disease soon rendered it impracticable to attempt the immunization of healthy herds on farms surrounding an infected farm, for the reason that the supply of serum and the number of inspectors were insufficient to carry out that plan. For each infected herd it would have been necessary to treat from 4 to 6 neighboring herds. This was only one of the difficulties encountered. In the beginning of the work, particularly, the farmers as a whole were apathetic and showed little interest in the experiments. Many were skeptical concerning the value of the serum, and it was not unusual to find in districts supposed to be canvassed by cooperating farmers herds which had already been infected for weeks without any report whatever of the condition having been made to the inspectors.

Thus it will be seen that at the very outset the carefully prepared plan of procedure was found to be impracticable, chiefly because of extensive infection and the lack of interest displayed by the farmers themselves. Therefore a change in the details of the work was decided upon. The immunization of healthy herds in the neighborhood of outbreaks was abandoned. More time was given to educational work through addresses to assemblages of farmers and by personal visits to individuals residing in the vicinity of infected farms. This educational work was directed particularly toward explaining the ways in which hog cholera is spread and urging the importance of sanitation and the establishment of a voluntary quarantine against infected farms. The properties and limitations of anti-hog-cholera serum were also fully discussed.

From what has been said it will be seen that these experiments for the study of the control of hog cholera partook only to a small degree of the characteristics of the usual control methods. Strict sanitary police measures were replaced by organization and education, and force was replaced by argument and explanation. Now, after three years of effort, the original indifference to the work has, for the most part, been replaced by genuine interest and willingness to cooperate on the part of farmers. It is interesting to consider the results.

## RESULTS OF FIELD EXPERIMENTS.

The results of this work may be considered from four different viewpoints: (1) Cost of the work; (2) prevalence of the disease; (3) losses from cholera; and (4) condition of the hog industry.

### COST OF THE WORK.

The principal item of expense in connection with this work is the salary list of field inspectors. Next in importance is the cost of the serum, and to these two items must be added charges for transportation, equipment, and general supervision. The cost per county to the Federal Government has averaged a little less than $9,000 a year. In most cases the amount expended by the States has been small, and it is safe to say that the total expenditures on the average have not exceeded $10,000 per county per annum.

### PREVALENCE OF THE DISEASE.

The actual effect of this work upon the prevalence of hog cholera is difficult to determine. As shown by figure 1, the disease, considering the country as a whole, varies in prevalence from year to year. Furthermore, these experiments began at a time (1913) when hog cholera had almost reached the pinnacle of one of the periodic waves of prevalence. During 1914 there was a decrease in some sections and in 1915 the disease was on the decline in the country as a whole, though it is true that in some localities it did not materially abate. Bearing these facts in mind, we may consider the number of outbreaks (that is, individual farms upon which the disease appeared) that occurred in the several areas during the experimental period, as shown in Table 1.

TABLE 1.—*Number of infected farms in counties where experimental work was carried on, 1913–1916.*

| State. | County. | Farms infected. | | |
|---|---|---|---|---|
| | | 1913 [1] | 1914 | 1915 |
| Georgia | Decatur | | 764 | 250 |
| Idaho | Twin Falls | | 92 | 103 |
| Indiana | Hendricks | | 446 | 247 |
| Do | Montgomery | 376 | 324 | 393 |
| Iowa | Clay | | 130 | 32 |
| Do | Dallas | 324 | 302 | 82 |
| Kansas | Marshall | | 278 | 48 |
| Kentucky | Henderson | | 157 | 163 |
| Michigan | Branch | | 96 | 19 |
| Minnesota | Renville | | 616 | 74 |
| Missouri | Pettis | 211 | 324 | 281 |
| Nebraska | Gage and Johnson | | 420 | 86 |
| South Dakota | Davison | | 269 | 116 |
| Tennessee | Maury | | 517 | 462 |

[1] Only 3 experimental counties in 1913.

It is unfortunate that the data contained in this table do not cover a greater period of time and that similar information can not be furnished for a number of counties immediately surrounding each experimental county. Nevertheless considerable information is afforded by the table in its present condition.

For the purposes of analysis it will be sufficient to consider the records of the three original counties. The table shows that with respect to prevalence of cholera these counties are not in agreement, for while the number of outbreaks steadily declined in Dallas County, Iowa, they increased slightly in Montgomery County, Ind., in 1915, while in Pettis County, Mo., though somewhat reduced in 1915, they yet exceeded the record of 1913. What is the explanation of these figures and how are these differences to be accounted for?

A separate consideration of each of these counties is necessary to obtain an answer to these questions. As stated above, no figures are available on the number of outbreaks in surrounding counties during the same period. However, some data relative to total losses from cholera in neighboring territory have been obtained, and this information enables us better to understand the records of these three experimental counties.

With reference to Dallas County, the table shows that the disease was most prevalent in 1913, slightly reduced in 1914, and greatly reduced in 1915. It is a fact that hog cholera in the State of Iowa as a whole followed somewhat the same course, being much less in extent in 1915 than in either of the two preceding years. Furthermore, a carefully prepared estimate, following personal investigations of the losses of hogs in 1913, 1914, and 1915 in seven neighboring counties where no organized fight against cholera was being carried on, shows the same progressive decrease that occurred in Dallas County. The reduced losses in these counties must have been due in the main to a decreasing prevalence of disease. It is clear, then, that although the experimental work may have served to keep the number of outbreaks lower than it would otherwise have been, it can not be said that the reduction in outbreaks in Dallas County, Iowa, was due to that work alone.

It is very interesting to compare the records from Montgomery County, Ind., with those from Dallas County, Iowa. In the former area the disease during the three years of work has shown little change in prevalence. It decreased slightly in 1914, only to increase in about the same degree in 1915. It is a matter of record that throughout the State of Indiana hog cholera showed no indication of decreasing in prevalence during the same period. On the contrary there were indications of increased prevalence in the State, taken as a whole, particularly in 1915. A personal canvass of four Indiana counties adjoining Montgomery County showed that in them the percentage of loss from cholera increased steadily during the three years. In other words, in these neighboring counties where no systematic work was done the disease seems to have pursued about the same course with respect to prevalence as in Montgomery County, where continued work was carried on. Of course the actual losses in Montgomery County were much less than in the surrounding counties, due to more general use of serum.

In Pettis County, Mo., the results were much the same, though it may be noted that there was no increase in prevalence there in 1915. In counties adjoining Pettis there appeared to be a distinct increase in the percentage of hogs lost from cholera.

It seems unnecessary to consider individually the remaining experimental counties where only two years' work has been done as against three years' work in those just discussed.

The fact that the control work did not serve to eradicate the disease is self-evident. Considering the records of outbreaks in the three original counties in comparison with the losses in neighboring counties during the years 1914 and 1915, we must conclude that the reduced prevalence in most of the experimental counties is probably a fortuitous circumstance, and at most only partly attributable to the experimental control work. It must be borne in mind, however, that these conclusions refer only to prevalence of outbreaks of disease and not to losses from cholera, for with regard to losses the case is entirely different.

## LOSSES FROM CHOLERA.

It will be remembered that in all of the experimental counties one of the duties of the field inspectors was to search out the infected farms and apply the serum treatment. This work had a dual purpose—to save the hogs and to cut short the disease, thereby minimizing the chances of its spreading. We have seen that the second object was not attained to any appreciable degree. The effect of the work upon the actual losses of hogs from disease is a subject that requires more extended consideration.

TABLE 2.—*Statistics of hogs raised and hogs that died of hog cholera in 14 experimental counties, 1912–1915.*

| County and State. | Date work begun. | 1912 | | | 1913 | | |
|---|---|---|---|---|---|---|---|
| | | Hogs raised. | Hogs died. | | Hogs raised. | Hogs died. | |
| | | *Number.* | *Number.* | *Per 1,000.* | *Number.* | *Number.* | *Per 1,000.* |
| Decatur, Ga | Aug. 25, 1914 | 48,418 | 8,546 | 176 | 52,797 | 12,225 | 231 |
| Twin Falls, Idaho | July 6, 1914 | 47,673 | 3,163 | 66 | 82,563 | 12,978 | 157 |
| Hendricks, Ind | Sept. 3, 1914 | 63,259 | 13,532 | 204 | 72,211 | 12,908 | 178 |
| Montgomery, Ind | July 5, 1913 | 77,403 | 24,404 | 315 | 78,813 | 5,136 | 64 |
| Clay, Iowa | July 10, 1914 | 73,065 | 25,000 | 342 | 87,953 | 30,266 | 344 |
| Dallas, Iowa | July 1, 1913 | 84,618 | 19,821 | 234 | 118,550 | 12,000 | 101 |
| Marshall, Kans | July 6, 1914 | 65,294 | 3,853 | 59 | 72,036 | 7,230 | 100 |
| Henderson, Ky | July 22, 1914 | 35,814 | 8,743 | 244 | 30,866 | 3,934 | 127 |
| Branch, Mich | May 28, 1914 | 46,170 | 1,209 | 25 | 55,338 | 4,039 | 72 |
| Renville, Minn | May 8, 1914 | 65,790 | 8,998 | 136 | 85,699 | 43,403 | 564 |
| Pettis, Mo | Aug. 1, 1913 | 59,661 | 18,853 | 316 | 107,151 | 6,386 | 59 |
| Gage and Johnson, Nebr | Mar. 31, 1914 | 76,591 | 5,445 | 70 | 80,949 | 6,012 | 74 |
| Davison, S. Dak | Oct. 6, 1914 | 39,920 | 2,270 | 36 | 57,695 | 16,248 | 281 |
| Maury, Tenn | July 21, 1914 | 73,234 | 8,399 | 114 | 69,787 | 6,360 | 91 |
| Total | | 856,910 | 152,236 | 177 | 1,052,408 | 179,125 | 170 |

| County and State. | Date work begun. | 1914 | | | 1915 | | |
|---|---|---|---|---|---|---|---|
| | | Hogs raised. | Hogs died. | | Hogs raised. | Hogs died. | |
| | | *Number.* | *Number.* | *Per 1,000.* | *Number.* | *Number.* | *Per 1,000.* |
| Decatur, Ga | Aug. 25, 1914 | 55,000 | 11,618 | 211 | 80,000 | 7,595 | 95 |
| Twin Falls, Idaho | July 6, 1914 | 100,000 | 1,269 | 12 | 150,000 | 1,487 | 10 |
| Hendricks, Ind | Sept. 3, 1914 | 85,955 | 4,065 | 42 | 107,205 | 3,075 | 29 |
| Montgomery, Ind | July 5, 1913 | 85,119 | 2,296 | 26 | 141,000 | 5,179 | 37 |
| Clay, Iowa | July 10, 1914 | 89,874 | 4,209 | 46 | 92,703 | 578 | 6 |
| Dallas, Iowa | July 1, 1913 | 138,320 | 6,810 | 49 | 124,540 | 1,939 | 16 |
| Marshall, Kans | July 6, 1914 | 65,592 | 3,432 | 52 | 101,207 | 561 | 5 |
| Henderson, Ky | July 22, 1914 | 20,000 | 2,907 | 145 | 20,000 | 1,980 | 99 |
| Branch, Mich | May 28, 1914 | 57,878 | 715 | 12 | 60,000 | 210 | 4 |
| Renville, Minn | May 8, 1914 | 100,722 | 5,069 | 50 | 108,360 | 347 | 3 |
| Pettis, Mo | Aug. 1, 1913 | 136,030 | 5,847 | 42 | 149,633 | 2,906 | 19 |
| Gage and Johnson, Nebr | Mar. 31, 1914 | 71,059 | 3,541 | 49 | 78,164 | 744 | 9 |
| Davison, S. Dak | Oct. 6, 1914 | 45,430 | 4,891 | 107 | 49,000 | 1,261 | 26 |
| Maury, Tenn | July 21, 1914 | 70,250 | 3,194 | 45 | 72,832 | 3,103 | 42 |
| Total | | 1,121,229 | 59,863 | 53 | 1,334,644 | 30,965 | 23 |

Table 2 gives in condensed form a record of losses from cholera in each of the 14 experimental counties for the years 1912 to 1915, inclusive. The table also shows the date upon which work was begun in each county. It is important to keep this date in mind in studying the table to determine the effect of the work upon the course of the disease, for as the work began 12 months earlier in some counties than in others the effects naturally became apparent in different years. The figures given are not merely estimates, but, on the contrary, were obtained by a personal canvass of the counties and may therefore be regarded as reasonably exact. The figures in the columns showing the total deaths represent the total losses of hogs from cholera. A large proportion of these occurred either in herds where no treatment was applied, because the disease was not reported, or took place in herds before inspectors could apply the treatment. Striking evidence of this is obtained by comparing the total deaths from cholera in 1914 and 1915 with the deaths among treated hogs during the same period. For example, the total deaths in 1914 numbered 59,863, of which only 13,985 hogs had been treated. In 1915, though there was a total loss of 30,965 hogs, only 9,148 of these had been treated. The prompt treatment of all hogs on infected farms undoubtedly would have reduced the losses still further.

Inasmuch as the experimental work was carried on in only 3 of the 14 counties in 1913, that year may be regarded as a fair representative of conditions in the 14 counties, taken as a whole, when the work was begun. By comparing the death rate in 1913 with that in 1914 and 1915, we find that not only did the actual losses from cholera steadily diminish, but that the ratio of deaths per thousand decreased to an even greater extent, due to increased hog production. In 1914 there were 119,262 fewer hogs lost than in 1913, and in 1915, 28,898 fewer than in 1914. The death rates for the same years were: 1913, 170 per thousand; 1914, 53 per thousand; and 1915, 23 per thousand.

During this same period we find that the number of hogs raised was constantly increasing, the number being 1,052,408 in 1913, 1,121,229 in 1914, and 1,334,644 in 1915, an increase of 282,236 hogs in two years.

Again, the question naturally arises as to whether this remarkable improvement with respect to losses and to the conditions of the industry is to be referred primarily to the natural subsidence of the disease or to the experimental control work. To decide this we must have recourse to comparison with neighboring counties. It has been possible to obtain what are believed to be reasonably accurate estimates of hogs raised and hogs lost during 1913, 1914, and 1915 in several counties surrounding each of seven of the experimental counties, namely, Dallas County, Iowa, Pettis County, Mo., Montgomery County, Ind., Clay County, Iowa, Gage and Johnson Counties, Nebr., Marshall County, Kans., and Renville County, Minn. The experimental work was begun in the first three of these counties in 1913 and in the remaining four in 1914. Therefore in making our comparisons it is necessary to divide the experimental counties into two groups, one representing counties in which work was done for three years, and the other those in which only two years' work was carried out. Table 3 contains the data relative to the first group and Table 4 those of the second group.

TABLE 3.—*Comparison of hogs raised and lost in 3 original experimental counties and 15 surrounding counties, 1912–1915.*

| Counties. | 1912 | | | 1913 | | | 1914 | | | 1915 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hogs raised. | Hogs lost. | | Hogs raised. | Hogs lost. | | Hogs raised. | Hogs lost. | | Hogs raised. | Hogs lost. | |
| | *Number.* | *Number.* | *Per 1,000.* | *Number.* | *Number.* | *Per 1,000.* | *Number.* | *Number.* | *Per 1,000.* | *Number.* | *Number.* | *Per 1,000* |
| Average of 3 experimental counties | 73,984 | 21,025 | 284 | 101,504 | 7,840 | 77 | 119,823 | 4,984 | 41 | 138,391 | 3,341 | 24 |
| Average of 15 surrounding counties | ........ | ........ | ........ | 80,993 | 14,858 | 183 | 67,888 | 7,977 | 117 | 58,021 | 5,593 | 96 |

Experimental counties: Dallas, Iowa; Montgomery, Ind.; and Pettis, Mo. Experimental work began in 1913.

TABLE 4.—*Comparison of hogs raised and lost in 4 experimental counties and 18 surrounding counties, 1913–1915.*

| Counties. | 1913 | | | 1914 | | | 1915 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Hogs raised. | Hogs lost. | | Hogs raised. | Hogs lost. | | Hogs raised. | Hogs lost. | |
| | *Number.* | *Number.* | *Per 1,000.* | *Number.* | *Number.* | *Per 1,000.* | *Number.* | *Number.* | *Per 1,000.* |
| Average of 4 experimental counties | 81,659 | 21,727 | 266 | 81,811 | 4,062 | 49 | 95,108 | 557 | 5 |
| Average of 18 surrounding counties | 53,997 | 16,734 | 309 | 44,028 | 7,230 | 164 | 47,113 | 3,877 | 82 |

Experimental counties: Clay, Iowa; Gage and Johnson, Nebr.; Marshall, Kans.; and Renville, Minn. Experimental work began in 1914.

Tables 3 and 4 seem to show clearly the effects of the experimental work. Considering first Table 3, it is remarkable to see the great reduction in losses from cholera in Dallas, Montgomery, and Pettis Counties in 1913 as compared with 1912, and to note that the loss per thousand was but little more than one-third of that which occurred in 1913 in the 15 neighboring counties where no experimental work was being done. It is seen also that the loss per thousand has continued to decrease during 1914 and 1915 in both cases, and that in the case of 3 experimental counties it has remained constantly from two and one-half to four times less than in the 15 surrounding counties. These results were obtained notwithstanding the fact that in the experimental counties considerably more hogs were being raised.

Table 4 presents additional data obtained from a different set of counties. It shows that in the four experimental areas consisting of Clay County, Iowa, Gage and Johnson Counties, Nebr., Marshall

County, Kans., and Renville County, Minn., there was a marked reduction of losses, both absolute and relative, immediately following the beginning of the control work, and that the average number lost in each experimental county in comparison with the average loss in neighboring counties was reduced from somewhat more than an equal number in 1913 to less than one-seventh in 1915.

Furthermore, it is important to note that Tables 3 and 4 both show that the work did not in any way injure the business of hog raising, but on the contrary seems to have aided it greatly. The very large increase in the number of hogs raised in the experimental counties, as compared with a languishing industry in the surrounding counties, is one of the most encouraging indications furnished by the data.

It will be remembered that the experimental work was based principally upon (1) an educational campaign, designed to stimulate the interest and secure the cooperation of farmers, and (2) the prompt treatment of infected herds with serum. This mode of procedure resulted in greatly increased hog production and greatly reduced mortality from cholera. It seems reasonable to ascribe the increase in hog production to the educational work, and the reduced losses from disease to the use of anti-hog-cholera serum. Table 5 summarizes the results following the use of serum in infected herds.

TABLE 5.—*Results of treatment in infected herds during 1913, 1914, and 1915.*

| Condition of hogs and method of treatment. | Hogs treated. | Hogs died. | |
|---|---|---|---|
| | *Number.* | *Number.* | *Per cent.* |
| Hogs sick when treated: | | | |
| Simultaneous | 2,448 | 713 | 29.1 |
| Serum alone | 83,099 | 23,990 | 28.8 |
| Total sick hogs treated | 85,547 | 24,703 | 28.8 |
| Hogs apparently well when treated: | | | |
| Simultaneous | 81,289 | 3,070 | 3.7 |
| Serum alone | 67,300 | 3,063 | 4.5 |
| Total healthy hogs treated | 148,589 | 6,133 | 4.1 |
| Total hogs treated | 234,136 | 30,836 | 13.1 |

Table 5, which shows that only 13.1 per cent of 234,136 hogs treated in infected herds were lost, seems to demonstrate clearly that potent serum is effective in preventing losses from cholera and that the reduced losses in the experimental counties are to be ascribed directly to the use of the serum.

## THE COMBATING OF HOG CHOLERA.

There are two facts which stand out clearly with respect to hog cholera. First, eradication or total extirpation of the disease in the United States at this time is impracticable. Second, though eradication is impossible, it is entirely practicable in large part to eliminate, by the use of serum, the enormous losses which annually are caused by the disease.

We are firmly convinced that, for the present, the greatest good is to be accomplished by bending every effort toward the rational use of serum so as to curtail the losses of hogs, rather than by attempting nation-wide eradication, which on account of the many factors involved we must regard as impossible. It is well, therefore, to consider how the most effective work may be done, and in particular what duties devolve upon the State and Federal Governments.

First of all we must recognize the fact that success or failure will depend upon the farmer himself. His interest and intelligent cooperation are the foundation stones upon which this work must rest. Therefore, education of farmers in matters pertaining to hog cholera takes first place. However, the importance of organization must not be lost sight of. Every farmer should be interested in and have knowledge of the conditions prevailing in neighboring herds and should see to it that his neighbors are promptly informed of any trouble that may arise in his own herd. To promote this cooperation, some form of organization of farmers is essential.

The whole purpose of this education and organization is to enable the farmers intelligently to avail themselves of the means of saving their hogs; therefore knowledge on the part of the farmer as to what to do and how to do it will be of little avail unless the needed facilities are supplied. Thus, arrangements must be made for ready availability of good serum and of the instruments required for its injection by men sufficiently skilled to insure proper use.

We may expect success in controlling losses from cholera when the following four conditions are met: (1) A farming community that knows hog cholera, the ways in which it is spread, and the best methods of combating it. (2) A community so organized that every farmer will be ready to help his neighbors by informing them of the existence of cholera wherever this may come to his notice, and where every farmer knows where to get good serum quickly. (3) Readily available serum at reasonable prices. (4) A sufficient number of skilled men to apply the serum.

In order to attain these desired conditions the united efforts of State and Federal Governments are required, for, while the prevention of losses in individual localities is a matter of local concern only, this disease, being so widespread and so disastrous in its effects upon the welfare and prosperity of the farmers generally, also affects the entire population of the country through the destruction of so large a proportion of the food-producing animals.

It seems clear, therefore, that the Federal Government should lend its aid in all cases where State officials or other local agencies are in a position to offer reasonable cooperation. Under such an arrangement the duties of Federal and State officials may be outlined as follows:

### DUTIES OF UNITED STATES DEPARTMENT OF AGRICULTURE.

The United States Department of Agriculture should supply a corps of trained veterinarians, one or more to be assigned to each State, where arrangements for cooperative work can be made. The duties of these field men would be to work in direct cooperation with the constituted authorities of the States in organizing the farmers, making addresses on cholera and means of control, and explaining and demonstrating the best methods of applying serum. These Federal field men should not remain permanently in one locality, but after working over a selected area should proceed to another and work there with State authorities as in the first, the idea being for them to help in organizing and coordinating the work, but ultimately leaving the administration entirely in the hands of State authorities.

The department should continue to inspect and supervise establishments engaged in the preparation of anti-hog-cholera serum for interstate shipment, the prime object of such inspection being to insure, in so far as supervisory inspection may accomplish that end, the purity and potency of the products which farmers will be encouraged to use.

### DUTIES OF STATE AUTHORITIES.

The State authorities should supply a corps of veterinarians who are particularly skilled not only in matters pertaining to hog cholera, but in the art of teaching and organizing. These men should work directly with the Federal officers and along the same lines, except that their work should perhaps go more into detail and their contact with farmers and farmers' organizations should be more intimate than would be the case with the Federal employees. They should also lend their cooperation to representatives of the live-stock sanitary board or chief veterinary officer of the State, so as to promote the observance of the sanitary rules which may be of the greatest assistance in limiting the number of outbreaks to be dealt with.

The State live-stock sanitary board or the State veterinarians should promulgate regulations designed to reduce the channels through which cholera may be spread, but framed at the same time with the idea of avoiding serious interference with the hog industry. At the same time a campaign of education relative to sanitation should be carried on in cooperation with the State college and the Federal Government. A force of men sufficient to attend to this work and to take part in the intensive work in selected areas would, of course, be needed.

The State live-stock sanitary board or the State veterinarian (except in States where such work is delegated to the State college) should maintain close supervision and inspection of all establishments producing anti-hog-cholera serum for use only within the State. It would not be essential for such inspection to be carried out at plants where Federal inspection is maintained. There appears to be no good reason for duplicating this work, but there is much reason for insisting upon the same standard of excellence for all serum that is to be sold to farmers, and this can be accomplished only by uniform methods of inspection.

## CONTROL OF SERUM AND VIRUS.

In addition to the duties described above for the three organizations concerned, there is certain other work to be done which might perhaps be assigned to either the one or the other of the two State organizations, the decision in this respect to be governed by local conditions and by the State laws in force. Among such duties may be mentioned the control of the use of virus in immunization work and the arrangement for the maintenance of supplies of serum, if such supplies are not already available, by private or public serum plants and in localities where all farmers may quickly procure it. This last-named need is of course essential, for when serum is needed it is needed quickly, and any delay in this respect might entirely nullify all of the other work. There is no justification for the expenditure of large sums to demonstrate and explain the use of serum unless serum can be obtained when needed. This problem should present little difficulty, for besides the considerable number of State plants, there are now in the country a large number of well-equipped private firms producing serum in large quantities, and these, with the State plants, are capable of supplying any demand that is likely to arise.

## COST OF CARRYING ON THE WORK.

It may be well in conclusion to say a few words concerning the cost of carrying out a plan such as that here suggested. It would probably be unwise to attempt to cover the entire country at the very beginning, for work of this kind is best done by experienced men who will proceed carefully and thus avoid the annoyances and confusion that would follow hasty or ill-advised action. Men of this type are not readily procured. Therefore it will be best to make a slow start, first giving attention to certain sections of a State, and when these are properly organized, proceeding to another. With this idea in mind it is suggested that the Federal Government might supply a force of 50 or 60 skilled men for field service at an annual cost, at the beginning, of about $200,000. This would enable the Federal Government to place 3 men in each of about 20 States. The States at the same time should supply for education and organization at least as many men as the Federal Government, and double the number would perhaps better fit the needs of the case. On the basis of an equal number, each State would need an appropriation of $10,000 annually for this work, and an equal sum should be available for the use of the State veterinarian in the campaign for improved sanitation. The cost of the needed serum should of course be borne by the farmers themselves.

This is a very modest program for dealing with a disease which annually causes losses amounting to many millions of dollars. However, it is believed best to proceed slowly and surely and in such a way that the farmers may be encouraged to do the greater part of the work themselves.

This discussion should not be closed without laying emphasis upon the importance of further research on the cause, modes of dissemination, and methods of preventing hog cholera. While complete eradication does not seem feasible at the present time, it is entirely possible that further research may enable us to discover means whereby complete elimination of the disease may be eventually realized. This, of course, is the end for which all concerned should continually strive. Both Federal and State Governments should provide for research along the lines indicated.

## SUMMARY.

1. No feasible plan has yet been devised for the complete eradication of hog cholera, yet it is entirely possible to control the losses from the disease and thus place hog raising upon a relatively stable basis, freed for the most part from the cholera menace which has been for so many years the bugbear of swine growers.

2. The plan of slaughter of infected herds with strict quarantine and disinfection of premises, such as has been pursued successfully in combating foot-and-mouth disease, is entirely unsuitable for the control or eradication of hog cholera in the United States.

3. A campaign of education with the prompt and intelligent use of serum[1] increases the interest and confidence of farmers in hog raising and results in reduction of losses and greatly increased hog production.

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[1] The methods of administering serum are described in Farmers' Bulletin 834, "Hog Cholera: Prevention and Treatment," to which the reader is referred for a discussion of the "simultaneous" and "serum-alone" methods of treatment.

4. Potent anti-hog cholera serum, if used promptly and intelligently on infected herds, will save a large portion of hogs which would otherwise succumb.

5. To combat the disease successfully and carry out the program herein outlined, there must be hearty cooperation between farmers and swine raisers, State authorities (colleges, live-stock sanitary boards, and State veterinarians), and the Federal Department of Agriculture. With this assured, the scourge of hog cholera should be gradually but surely overcome.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 585

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief, and the Bureau of
Chemistry, CARL L. ALSBERG, Chief

Washington, D. C. ▼ October 18, 1917

# A GUIDE FOR FORMULATING A MILK ORDINANCE.

PREPARED IN THE DAIRY DIVISION OF THE BUREAU OF ANIMAL INDUSTRY AND IN THE BUREAU OF CHEMISTRY.

For the proper safeguarding of the milk supply of a community a suitable and enforceable law must first be enacted. In general this law must cover three distinct phases: First, fraud; second, disease; and third, cleanliness in the production and handling of milk. One of the most important considerations must be the reasonableness of the law. A law which works a special hardship on a legitimate industry is not reasonable, and a law so stringent that it can not readily be enforced will defeat its own ends.

A study[1] of the milk ordinances of a great many cities, large and small, shows that there is a great diversity of opinion among the lawmakers and their advisers as to what constitutes a proper milk ordinance. There is certainly a great lack of uniformity among the laws, some of which are entirely out of date. Many of them seem to be transcripts of ordinances in force in other cities, placed in the municipal series of laws without regard to local conditions. Some of them contain provisions which are unnecessary and unreasonable and which can not be enforced.

There has been a constant demand on the Dairy Division of the Bureau of Animal Industry by municipal authorities for some form of milk ordinance which will best meet the requirements necessary to obtain a good, clean, safe milk supply, and which can be used as a guide for local communities.

In a strict sense it is impossible to frame a milk ordinance, with its definitions, standards, and requirements, which will be suitable for all communities. On the other hand, a general skeleton form may be made that can be used as a framework upon which to build a finished, practicable, operative law. No local lawmaking body should attempt to draft a milk ordinance, with its standards, grades, and requirements, unless it is entirely familiar with local dairy and milk conditions, as well as with the purposes and intent of such an ordinance. A special study by competent authority should be made.

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[1] Report of the Committee on Statistics of Milk and Cream Regulations of the Official Dairy Instructors' Association, printed in vol. 1, No. 1 (May, 1917), Journal of Dairy Science.

In that way only can satisfactory standards—chemical, bacteriological, and sanitary—be prescribed.

With those ideas in view, the Bureau of Animal Industry and the Bureau of Chemistry have prepared a form of milk ordinance which, it is believed, if enacted and enforced, would assist the community in providing an instrument for bettering its milk supply.

The ordinance is restricted to the production, handling, and sale of milk and cream as such. It consists of eight sections, taking into consideration definitions, standards, grades, adulterations, the making of regulations, the collection of samples, and penalties.

A special feature of the ordinance is the grading of milk and cream. It is believed that grading is necessary and is of paramount importance. One of the great sanitary and economic questions will be solved if practical grading of milk, with the consequent grading of selling price, can be enforced. Three grades are considered—"Certified," grade A, and grade B. Pasteurization is compulsory for grade B, but optional for the others. Grades A and B represent the largest quantities of milk sold. No definite general score or bacterial requirements can be made to cover all conditions. Some communities, long under competent health jurisdiction, can enact and enforce more stringent laws than other communities not so fortunate. The health department must determine from its own experience the score and bacterial count for grades A and B. Grade A must be of such quality that there will be no question as to its purity and safety. Grade B can be of lower grade than A, because pasteurization is obligatory. No grade below that of B is recognized.

Another item of special importance is the provision which gives health authorities the right to make regulations for the further proper enforcement of the ordinance. That is a wise provision, as rules or regulations can define more fully and add necessary detail, and can be passed and amended without the difficulty encountered with general lawmaking bodies. The regulations can give details for the issuing of permits, for the examination of herds and milkers for disease, and for the cleanly production and handling of milk. They can not, however, go beyond the scope expressed in the ordinance itself.

It is believed that this draft of an ordinance will prove to be a satisfactory framework upon which the average town or city can build a finished, practicable law, which, if properly enforced, will improve the average milk supply and work toward a desired uniformity of food laws.

## FORM OF ORDINANCE.

### AN ORDINANCE TO REGULATE THE PRODUCTION AND SALE OF MILK AND CREAM, AND FOR OTHER PURPOSES.

*Be it ordained by the* ——— *of the city of* ———, That for the purpose and within the meaning of this ordinance, (*a*) "milk" is the lacteal secretion obtained from the complete milking of cows; (*b*) "skimmed milk" is milk from which substantially all of the milk fat has been removed; (*c*) "certified milk" is milk produced and handled in conformity with the "Methods and Standards for the

Production and Distribution of Certified Milk," adopted by the American Association of Medical Milk Commissions May 1, 1912, and amendments thereto, in effect at the time of production, and certified to by a milk commission constituted in compliance therewith; (*d*) "grade A milk" is milk produced from healthy cows, as determined by the tuberculin test and physical examination within not exceeding one year previously by a qualified veterinarian, from dairies that score not less than —— on the dairy-farm score card in current use at the time by the United States Department of Agriculture, which milk shall not, at any time, contain more than ——— bacteria per cubic centimeter; (*e*) "grade B milk" is milk produced from healthy cows, as determined by physical examination within not exceeding one year previously by a qualified veterinarian, from dairies that score not less than —— on the dairy-farm score card in current use at the time by the United States Department of Agriculture, which milk shall not, at any time, contain more than ——— bacteria per cubic centimeter; (*f*) "pasteurized milk" is milk which has been heated to, and for at least 30 minutes held at, a temperature of approximately 145, never less than 142, degrees Fahrenheit; (*g*) "cream" is that portion of the milk, rich in milk fat, which rises to the surface of the milk on standing, or is separated from it by centrifugal force, and containing not less than —— per cent of milk fat; (*h*) "homogenized," or "emulsified," milk or cream is milk or cream which has been subjected to the mechanical process of homogenization, or of emulsification, as the case may be; (*i*) "unsterilized containers" are containers which either have not been subjected to moist heat at a temperature as high as 205 degrees Fahrenheit for two minutes or longer, or do not comply with such alternative requirements, to be prescribed by the regulations made pursuant to this ordinance, as may be necessary to effect sterilization thereof; and (*j*) "person" imports both the plural and the singular, as the case demands, and includes corporations, partnerships, societies, and associations.

When construing and enforcing the provisions of this ordinance, the act, omission, or failure of any officer, agent, or other person acting for or employed by any individual or by any corporation, partnership, society, or association, within the scope of his employment or office, shall in every case be also deemed to be the act, omission, or failure of such individual, corporation, partnership, society, or association, as well as that of such officer, agent, or other person.

SEC. 2. That no person shall sell or deliver for consumption as milk or cream or have in his possession with intent to sell or deliver for consumption as milk or cream either—

(*a*) Milk or cream to which water or any foreign substance has been added; or

(*b*) Milk containing less than —— per cent of milk fat or less than —— per cent of solids not fat, or cream containing less than —— per cent of milk fat, unless such milk or cream is plainly and conspicuously labeled "Subnormal," together with a statement showing the actual per cent of milk fat contained therein; or

(*c*) Skimmed milk which has not been pasteurized, or made from pasteurized milk, or which is not labeled "Skimmed Milk"; or

(*d*) Milk or cream containing, or which has been exposed to, any disease-producing bacteria; or

(*e*) Milk or cream the container of which is labeled or branded so as to mislead or deceive the purchaser; or

(*f*) Milk or cream produced from diseased cows, or from cows during the period of 15 days preceding parturition or within such time thereafter as the milk is abnormal, or from cows which have been fed unwholesome food or have had access to contaminated water; or

(*g*) Milk or cream which falls below the requirements of grade B, as defined herein, or milk or cream which has been produced, stored, handled, or transported in any unclean or insanitary manner; or

(*h*) Milk or cream the retail, or the final, container of which does not bear a plain and conspicuous statement showing the kind and grade as herein defined; or

(*i*) Milk or cream in unsterilized containers; or

(*j*) Milk or cream which such person has kept at a temperature higher than 50 degrees Fahrenheit; or

(*k*) Grade B milk which has not been pasteurized; or

(*l*) Homogenized milk or cream, or emulsified milk or cream, unless it is plainly and conspicuously labeled "Homogenized," or "Emulsified," as the case may be; or

(*m*) Milk which has had the cream line increased by any artificial means.

SEC. 3. That nothing in this ordinance shall be construed to prohibit the sale, when labeled so as to show its true character, of either (*a*) sour milk or sour cream; or (*b*) buttermilk, or any similar product made from pasteurized milk or cream; or (*c*) modified milk if made from milk or cream equal at least to grade B.

SEC. 4. That no person shall sell or deliver, or have in his possession with intent to sell or deliver, for consumption as milk or cream, any milk or cream without a permit from the board of health of ———.

SEC. 5. That the board of health of ——— is authorized to make such regulations, from time to time, as are necessary for the efficient execution of the provisions of this ordinance, and to issue permits to sell and deliver milk or cream in ———. The board of health, after affording the permittee an opportunity for a hearing, may suspend or revoke any permit issued by it under this ordinance whenever it shall determine that the permittee has violated any of the provisions of this ordinance or of the regulations made hereunder, and, without affording such opportunity, may suspend such a permit temporarily whenever it deems necessary.

SEC. 6. That the board of health of ———, its members, officers, and agents, shall, at all reasonable times, have access to any dairy or any other place where milk or cream is produced for sale; to any wagon, truck, train, car, warehouse, or station in which milk or cream for sale is being transported or is being held for transportation or delivery; and to all establishments, plants, depots, or stores where milk or cream is kept or stored for sale. Any person who hinders or prevents such access shall be guilty of a violation of this ordinance.

SEC. 7. That any producer, handler, or seller of milk, or cream, whether principal, agent, or employee, who, on demand, refuses to sell or deliver a sample, not to exceed one pint, of milk or cream in his possession to any official designated by the board of health to collect samples, shall be guilty of a violation of this ordinance.

SEC. 8. That any person violating any of the provisions of this ordinance shall, on conviction by any court of competent jurisdiction, be punished by a fine of not more than ——— dollars, or by imprisonment of not more than ———, or by both such fine and imprisonment, in the discretion of the court; and for each subsequent offense, and conviction thereof, shall be punished by a fine of not more than ——— dollars, or by imprisonment of not more than ———, or by both such fine and imprisonment, in the discretion of the court.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 586
Contribution from Office of Public Roads and Rural Engineering,
LOGAN WALLER PAGE, Director.

Washington, D. C. PROFESSIONAL PAPER February 28, 1918

# PROGRESS REPORTS OF EXPERIMENTS IN DUST PREVENTION AND ROAD PRESERVATION, 1916.

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During the year 1916 the Office of Public Roads and Rural Engineering undertook three new experimental highway projects and a separate investigation of corrugated metal pipe for use in constructing highway culverts. All of the highway projects involved the use of bituminous materials. The principal purpose of the new road experiments has been to develop the most advantageous methods of using gravel with bituminous materials in constructing the better types of roads. Other purposes have been to investigate the value, as a road-surfacing material, of earth-oil asphalt, made by admixing asphalt with a prepared mixture of earth and water; and to secure check results with certain types of bituminous macadam that have been employed in previous experiments of the office. The culvert investigation is for the purpose of determining the relative merits of various kinds of steel and iron used in the manufacture of corrugated pipe.

Supplementary reports, describing the progress of experiments previously reported, follow the reports of the new experiments. To these supplementary reports are added, in several cases, summaries showing an outline history of the projects to date. Also, the histories of several projects that have been discontinued are summarized in this bulletin so as to make the experimental results already obtained by the office easier for the interested reader to follow.

NOTE.—In this publication "bituminous macadam by the penetration method" is called simply bituminous macadam, and "bituminous macadam by the mixing method," bituminous concrete.

## NEW EXPERIMENTS.

The new experiments included bituminous macadam and bituminous gravel construction on the Russell Road in Alexandria County, Va.; bituminous gravel concrete and earth-oil asphalt on the Alexandria-Accotink Road in Fairfax County, Va.; and the bituminous surface treatment of a new gravel road leading from Gum Spring to Mount Vernon in Fairfax County, Va. In addition the special experiments with corrugated metal culverts were initiated on the Texas post road.

### EXPERIMENTS ON RUSSELL ROAD, ALEXANDRIA COUNTY, VA.

#### BITUMINOUS MACADAM AND BITUMINOUS GRAVEL.

This experimental project is located in Alexandria County, Va. The road begins at station 0+00 or station 114+47.3 of the Mount Vernon Avenue experimental road, and runs in a general southwesterly direction on a new location to station 21+40. From there it continues in the same general direction over an old worn-out gravel road to the city line of Alexandria. The project is 8,761.4 feet in length and is divided into eight experiments, as shown in Table 1. The experiments are numbered consecutively from station 0+00 toward Alexandria. The experimental surfaces were constructed on a 6-inch pit-run gravel base throughout. Work was begun by contract July 12, 1915, and completed June 20, 1916. The total cost of the project was $22,844.94.

TABLE 1.—*Description of experiments.*

| Experiment number. | Location (stations). | Stone. | Bituminous material. | |
|---|---|---|---|---|
| | | | First application. | Second application. |
| 1[1] | 1+81 to 17+81 | Trap | Water-gas tar, refined | Water-gas tar, refined. |
| 2 | 17+81 to 35+91 | do | do | Oil asphalt. |
| 3 | 35+91 to 54+55 | do | Coal tar, refined | Coal tar, refined. |
| 4 | 54+55 to 72+55 | do | do | Oil asphalt. |
| 5[2] | 72+55 to 77+55 | Gravel | Water-gas tar, refined | Water-gas tar, refined. |
| 6 | 77+55 to 82+61 | do | Oil asphalt | Oil asphalt. |
| 7[3] and 8 | 82+61 to 87+61.4 | do | Residual asphaltic petroleum. | Residual asphaltic petroleum. |

[1] The area from station 0+00 to station 1+81 at the intersection with the Mount Vernon Avenue experimental road was surfaced with the same kind of wearing course used on experiment No. 10 of that road and is classed with that experiment.

[2] From station 72+55 to station 73+46, 30 per cent of sand was added to the tar.

[3] The gravel for this experiment was a mixture of pit-run gravel from the Haney pit with ¾-inch screened gravel imported from Richmond, Va.

## GENERAL FEATURES OF THE PROJECT.

*Right of way and location.*—A new location was made from station 0+00 to station 21+40, in order to eliminate a railroad crossing at grade with the Washington & Old Dominion Railroad at station 12+50. The county of Alexandria secured this new right of way and and also arranged for widening the right of way of the old road to 50 feet throughout its length. The acquired right of way amounted to a total of 2.2 acres. All points of curvature and tangency of the new location lines were marked with 6-inch concrete bound stones, set with the back face center at the point.

*Clearing and grubbing.*—Including both old and new location, 5 acres were cleared and grubbed.

*Excavation.*—All excavating was done with drag and wheel scrapers and dump wagons. Wherever practicable, fills were made with wheel scrapers in uniform layers. Side-hill slopes under new fills were plowed. Slopes in cuts were finished 1:1 and on fills 1½:1. The road was graded to a width of 24 feet, the shoulders being 4 feet wide and having a slope of 1 inch to a foot. The side ditches were excavated 19 inches below the grade of the road. The crown of the subgrade was made the same as the crown of the surface ⅜ inch to a foot. Between stations 63+50 and 86+50, 469 cubic yards of earth were borrowed. This borrow was made necessary because when the estimate was prepared, too small an allowance was made for shrinkage. In all, 11,384 cubic yards of earth were excavated.

*Grade crossing elimination.*—An agreement was made with the Washington & Old Dominion Railroad Co. whereby the company constructed, at its own expense, abutments and a bridge span for the elimination of the grade crossing at station 12+50. By the terms of this agreement, the Department of Agriculture removed the prism of earth below the railroad and dug the foundation pits for the abutments. The excavation of the foundation pits cost $335 64. The cost to the railroad company of its portion of the work was $2,588.76.

*Drainage.*—Subdrainage, culverts, catch basins, and paved gutters were built where needed.

*Foundation or base course.*—After the grading was completed, the subgrade was brought to its final shape by the use exclusively of picks and shovels and by rolling. All spongy and yielding areas were removed and replaced with fresh material as the rolling progressed. The foundation for all the experimental sections consisted of a compacted layer of gravel 6 inches in depth. A sand-clay gravel represented by the analysis given in Table 2 obtained from Haney's pit, adjoining the road, was used. All the gravel was weighed at the pit, and sample cubic yards loose also were weighed from time to time. A total of 5,604.4 tons of gravel was placed in the foundation. The average weight of a cubic yard of loose gravel was 3,000 pounds and the expansion from the pit to the wagon was 22 per cent. The gravel was dumped on the subgrade and spread by hand to a depth of 8.7 inches. Practically all the stones of size greater than would pass a 2½-inch screen were removed in the pit or while the gravel was being spread on the road. The gravel base was rolled with a 10-ton roller and was all in place December 4, 1915. Travel was allowed over the base all winter. Before beginning the experimental surfacing, April 10, 1916, light trimming and reshaping of the base had to be done, but no serious depressions or ruts had developed.

TABLE 2.—*Mechanical analysis of gravel for use in foundation.*

| | Per cent. |
|---|---|
| Passing 1-inch screen, retained on ¾-inch screen | 1.4 |
| Passing ¾-inch screen, retained on ½-inch screen | 15.7 |
| Passing ½-inch screen, retained on ¼-inch screen | 25.7 |
| Passing ¼-inch screen, retained on 10-mesh sieve | 19.6 |
| Passing 10-mesh sieve, retained on 20-mesh sieve | 10.1 |
| Passing 20-mesh sieve, retained on 30-mesh sieve | 5.1 |
| Passing 30-mesh sieve, retained on 40-mesh sieve | 3.2 |
| Passing 40-mesh sieve, retained on 50-mesh sieve | 3.8 |
| Passing 50-mesh sieve, retained on 80-mesh sieve | 3.2 |
| Passing 80-mesh sieve, retained on 100-mesh sieve | .8 |
| Passing 100-mesh sieve, retained on 200-mesh sieve | 2.4 |
| Passing 200-mesh sieve | 9.0 |
| Total | 100.0 |

*Shoulders.*—Earth shoulders were constructed 4 feet wide, with a slope of 1 inch to the foot. They were rolled and trimmed as the surface was completed.

*Guard-rails.*—Wooden guard-rails were constructed along the road 3 feet outside the edge of the bituminous surface at the stations shown in Table 3.

TABLE 3.—*Location of guard-rails.*

| Left. | Right. |
|---|---|
| Station 1+82 to Station 4+79 | Station 1+41 to Station 4+66 |
| Station 14+71 to Station 16+60 | Station 22+59 to Station 24+75 |
| Station 20+00 to Station 25+78 | Station 24+88 to Station 26+00 |
| Station 40+40 to Station 42+26 | Station 40+10 to Station 43+76 |
| Station 56+90 to Station 57+94 | Station 55+06 to Station 59+06 |
| Station 58+24 to Station 59+68 | Station 63+25 to Station 63+65 |
| Station 63+00 to Station 64+00 | Station 67+38 to Station 72+34 |
| Station 66+41 to Station 72+60 | Station 77+84 to Station 79+28 |
| Station 77+63 to Station 79+63 | |

Total, 4,519 linear feet.

## TESTS OF MATERIALS.

TABLE 4.—*Physical properties of trap rock used in the surface construction.*

| | |
|---|---|
| Specific gravity | 3.00 |
| Weight per cubic foot ... pounds | 187 |
| Water absorbed per cubic foot ... do | .43 |
| Per cent of wear | 2.6 |
| French coefficient of wear | 15.5 |
| Hardness | 18.3 |
| Toughness | 13 |
| Cementing value | Fair. |

TABLE 5.—*Mechanical analysis of gravel and sand used in the surface construction.*

| | Screened gravel for use in penetration experiments Nos. 5 and 6. | Clean sand for experiments Nos. 5 and 8. | Sand-clay gravel for experiments Nos. 7 and 8. | Pea-gravel for gravel experiments Nos. 5, 6, 7 and 8. |
|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Retained on 2 inch screen | 37.3 | | | |
| Passing 2-inch, retained on 1½-inch screen | 21.2 | | | |
| Passing 1½-inch, retained on 1¼-inch screen | 29.5 | | 4.7 | |
| Passing 1¼-inch, retained on 1-inch screen | 10.5 | | 0.4 | |
| Passing 1-inch, retained on ¾-inch screen | 1.5 | | 4.0 | |
| Passing ¾-inch, retained on ½-inch screen | | | 14.9 | 9.9 |
| Passing ½-inch, retained on ¼-inch screen | | | 23.6 | 50.4 |
| Passing ¼-inch, retained on 10-mesh sieve | | | 16.8 | 34.2 |
| Passing 10-mesh sieve retained on 20-mesh sieve | | 7.2 | 6.1 | 5.5 |
| Passing 20-mesh sieve retained on 30-inch sieve | | 19.6 | 3.7 | |
| Passing 30-mesh sieve retained on 40-mesh sieve | | 25.6 | 3.1 | |
| Passing 40-mesh sieve retained on 50-mesh sieve | | 22.4 | 2.5 | |
| Passing 50-mesh sieve retained on 80-mesh sieve | | 17.2 | 2.6 | |
| Passing 80-mesh sieve retained on 100-mesh sieve | | 1.6 | .5 | |
| Passing 100-mesh sieve retained on 200-mesh sieve | | 5.0 | 2.0 | |
| Passing 200-mesh sieve | | 1.4 | 15.1 | |
| Total | 100.0 | 100.0 | 100.0 | 100.0 |

TABLE 6.—*Mechanical analysis of trap rock used in surface construction of experiments 1, 2, 3, and 4.*

| | Trap rock for penetration. | Trap-rock chips. |
|---|---|---|
| | *Per cent.* | *Per cent.* |
| Retained 2-inch screen | 20.6 | ........ |
| Passing 2-inch, retained on 1½-inch screen | 37.5 | ........ |
| Passing 1½-inch, retained on 1¼-inch screen | 17.0 | ........ |
| Passing 1¼-inch, retained on 1-inch screen | 12.4 | ........ |
| Passing 1-inch, retained on ¾-inch screen | 9.1 | 15.0 |
| Passing ¾-inch, retained on ½-inch screen | 2.4 | 36.0 |
| Passing ½-inch, retained on ¼-inch screen | .9 | 37.0 |
| Passing ¼-inch, retained on 10-mesh sieve | [1]1.1 | 11.3 |
| Passing 10-mesh sieve | ........ | .7 |
| Total | 100.0 | 100.0 |

[1] Passing ¼-inch screen.

TABLE 7.—*Analysis of refined tars.*

| | Coal tar, refined. | | | Water-gas tar, refined. | | |
|---|---|---|---|---|---|---|
| | Experiments Nos. 3 and 4. | | | Experiments Nos. 1, 2, and 5. | | |
| Specific gravity 25°C/25°C | 1.206 | | | 1.150 | | |
| Float test 50°C | 2′38″ | | | 2′34″ | | |
| Soluble in $CS_2$ (total bitumen)..per cent | 84.99 | | | 98.28 | | |
| Free carbon...do | 14.96 | | | 1.65 | | |
| Inorganic residue upon ignition...do | .05 | | | .07 | | |
| Distillation. | Character. | Per cent by volume. | Per cent by weight. | Character. | Per cent by volume. | Per cent by weight. |
| Water | Trace. | 0.0 | 0.0 | Trace. | 0.0 | 0.0 |
| First light oils (to 110°C) | ...do... | .0 | .0 | ...do... | .0 | .0 |
| Second light oils (110° to 170°C) | Cloudy. | .2 | .1 | ...do... | .0 | .0 |
| Heavy oils (170° to 270°C) | ...do... | 10.2 | 7.9 | Cloudy. | 19.0 | 16.5 |
| Heavy oils (270° to 300°C) | ...do... | 10.0 | 8.1 | ...do... | 12.4 | 10.2 |
| Pitch | ........ | 79.6 | 83.8 | ........ | 68.6 | 73.3 |
| | | 100.0 | 100.0 | | 100.0 | 100.0 |

TABLE 8.—*Analyses of petroleum products.*

| | Oil asphalts. | | Residual asphaltic petroleum. |
|---|---|---|---|
| | Experiment No. 6. | Experiment Nos. 2 and 4. | Experiment Nos. 7 and 8. |
| Specific gravity 25°/25°C | 1.040 | 1.053 | 0.993 |
| Melting point, °C | 49 | 58 | ........ |
| Float test at 50°C (time) | ........ | ........ | 0′28″ |
| Specific viscosity Engler 100°C., 50cc | ........ | ........ | 14.9 |
| Penetration at 25°C., 100 grams, 5 sec | 98 | 58 | ........ |
| Loss, 5 hrs., 163°C., 20 grams, ...per cent | 3.01 | ........ | 13.98 |
| Penetration of residue, as above | 58 | 37 | ........ |
| Per cent of total bitumen insoluble in 86°B naphtha | 27.70 | 30.05 | 18.88 |
| Fixed carbon...per cent | 17.25 | 18.85 | 9.96 |
| Soluble in $CS_2$ (total bitumen)...do | 99.80 | 99.80 | 99.93 |
| Organic matter insoluble...do | .09 | .17 | .07 |
| Inorganic matter insoluble...do | .11 | .03 | .00 |
| | 100.00 | 100.00 | 100.00 |

## DESCRIPTION OF EXPERIMENTS.

### EXPERIMENT No. 1.—BITUMINOUS MACADAM: TRAP ROCK WITH REFINED WATER-GAS TAR.

Location, station 1+81 to station 17+81.
Total length, 1,600 feet.
Total area, 2844.4 square yards.

The gravel base, as mentioned, had been under traffic for 4 months before the experimental surface was begun. The base was in good condition and required only a small amount of trimming and reshaping. One and one-half inch trap rock, having the physical properties and the mechanical analysis shown in Tables 4 and 6, was hauled in dump wagons and spread by hand to a depth of 3 inches. The spread stone was rolled until well keyed for two or three stations in advance of the pouring of the bituminous material which was heated in 500-gallon kettles mounted on trucks. The tar, at a temperature of 250° to 300° F., was drawn off into 4-gallon hand-pouring pots and applied at the rate of 1½ gallons to the square yard. The distribution was controlled by pouring in longitudinal strips with as little lapping as possible.

Clean stone chips were spread on the surface while the bituminous material was still hot and were broomed to an even distribution while the surface was being rolled with a 10-ton macadam roller. A seal coat of the hot tar, slightly in excess of one-half gallon per square yard, was applied. Chips then were spread in such quantity as to cover all visible bituminous material and rolled immediately. The mechanical analysis of the chips is shown in Table 6.

### EXPERIMENT No. 2—BITUMINOUS MACADAM: TRAP ROCK WITH REFINED WATER-GAS TAR AS BINDER AND OIL ASPHALT FOR THE SEAL COAT.

Location, station 17+81 to station 35+91.
Total length, 1, 810 feet.
Total area, 3,217.7 square yards.

The construction of this experiment was exactly as described for experiment No. 1, except that an oil asphalt at a temperature of 275° to 350° F. was used as the seal coat and applied in the same quantity and manner as the tar seal coat in experiment No. 1.

### EXPERIMENT No. 3: BITUMINOUS MACADAM: TRAP ROCK WITH REFINED COAL TAR FOR BINDER AND SEAL COAT.

Location, station 35+91 to station 54+55.
Total length, 1,864 feet.
Total area, 3,313.7 square yards.

This experiment differs from experiments 1 and 2 only in the bituminous material.

### EXPERIMENT NO. 4.—BITUMINOUS MACADAM: TRAP WITH REFINED COAL TAR BINDER AND OIL ASPHALT SEAL COAT.

Location, station 54+55 to station 72+55.
Total length, 1,800 feet.
Total area, 3,311.1 square yards.[1]

This experiment differs from No. 2 only in the kind of tar used for the penetration course.

### EXPERIMENT NO. 5.—BITUMINOUS GRAVEL MACADAM, GRAVEL BEING GROUTED WITH MIXTURE OF SAND AND REFINED WATER-GAS TAR.

Location, station 72+55 to station 77+55.
Total length, 500 feet.
Total area, 888.8 square yards.

The gravel used in this experiment was received from Richmond, Va., and had been washed and screened. The mechanical analysis is shown in Table 5. The gravel was spread 3 inches thick, loose, and was rolled with a 10-ton roller. The fragments cracked slightly, and the surface tended to become wavy under the roller. After rolling the gravel, a grout of sand and refined water-gas tar was applied for the first 91 feet. The grout was mixed in the heating kettle in the proportion of about 3 parts of sand by volume to 5 parts of tar. The sand was not dry and considerable foaming in the kettle resulted. In mixing the materials it was found impossible to prevent the sand from settling to the bottom of the kettle, regardless of the care used in stirring, so that this method was abandoned. It had been expected to apply 1½ gallons of this mixture to the square yard. The section was covered with pea gravel, rolled, and a seal coat applied later, as described below. The remainder of the experiment was constructed as follows: A penetration coat of refined water-gas tar was applied as in experiment No. 1, and sand, as shown in the mechanical analysis of Table 5 was applied by shovels to the surface until all voids were filled. The surplus sand was swept off and areas showing voids were filled carefully. A seal coat of refined water-gas tar and pea gravel to the amount of 0.6 gallon of tar and about 0.02 cubic yard of pea gravel per square yard then was applied to the entire section. A final rolling with the 10-ton roller completed the section.

### EXPERIMENT NO. 6.—BITUMINOUS GRAVEL (PENETRATION METHOD). OIL ASPHALT FOR PENETRATION AND SEAL COAT.

Location, station 77+55 to station 82+61.
Total length, 506 feet.
Total area, 899.5 square yards.

Experiment No. 6 was built according to the same method employed in experiments Nos. 1 to 4, except that an asphaltic oil was used instead of tar for both the penetration and the seal coat, and clean screened gravel and pea gravel were substituted for the trap rock. The mechanical analyses of the gravels are shown in Table 5.

---

[1] Includes 111.1 square yards widening on curve.

### EXPERIMENT NO. 7.—GRAVEL CONSTRUCTION, WITH SURFACE TREATMENT OF RESIDUAL ASPHALTIC PETROLEUM.

Location, station 82+61 to station 85+61.
Total length, 300 feet.
Total area, 533.3 square yards.

In this experiment the surfacing was constructed of a 4-inch layer of pit-run gravel, upon which was placed a 1-inch layer of clean, washed gravel. The entire course was harrowed with a spike-tooth harrow, sprinkled thoroughly and rolled, after which the entire experiment was opened to traffic for one month. The surface, which then had become thoroughly compacted, was roughened with picks and harrowed loose to an average depth of 1 inch. The bituminous treatment followed immediately after the harrowing, and consisted of (1) an application of 0.68 gallon of hot residual asphaltic petroleum per square yard, covered with pea gravel, and rolled; and (2) an application of 0.55 gallon of the same oil per square yard, covered with sand, and rolled. After the surface had been finished for a day or two there was a tendency toward bleeding, and more sand was applied.

Experiment No. 8 was planned originally as a part of experiment No. 7, and no distinction was made between them in the records and cost data. Therefore they are considered together in other parts of this report.

### EXPERIMENT NO. 8.—(ORIGINALLY A PART OF EXPERIMENT NO. 7.)—GRAVEL CONSTRUCTION WITH SURFACE TREATMENT OF RESIDUAL ASPHALTIC PETROLEUM.

Location, station 85+61 to station 87+61.
Total length, 200 feet.
Total area, 355.5 square yards.

This experiment was similar in all respects to experiment No. 7, except as follows: The surface treatment consisted of a single application of hot residual asphaltic petroleum, at the rate of 0.693 gallon per square yard, with a covering of pea gravel. A thin coat of dry sand-clay, of very homogeneous quality was applied over the surface treatment without any additional oil, and rolling completed the experiment.

## SUMMARY OF COST DATA FOR ENTIRE PROJECT.

The cost data for the experiments described above are presented in Tables 9 to 16.

### TABLE 9.—*Cost data for grading and subgrade.*

| Items. | Clearing and grubbing. | Excavation. | Shaping. | Rolling.[1] | Subgrade, complete (total). |
|---|---|---|---|---|---|
| | *Acres.* | *Cubic yards.* | *Sq. yds.* | *Sq. yds.* | *Sq. yds.* |
| Quantity | 5.0 | 11,383.9 | 23,423.9 | 15,627.5 | 15,627.5 |
| Labor | $189.49 | $4,227.24 | $1,448.62 | $34.65 | $5,900.00 |
| Materials | | | | [2] 11.50 | 11.50 |
| Total cost | 189.49 | 4,227.24 | 1,448.62 | 46.15 | 5,911.50 |
| Unit cost | 37.89 | .371 | .6618 | .003 | .38 |

[1] Includes 7,796.4 square yards shoulders.

[2] Coal oil, etc.

### TABLE 10.—*Cost data for drainage structures.*

| Items. | Concrete culvert. | Pipe culvert. | French subdrain. | Cobble subdrain. | Open drain. | Concrete gutter. | Cobble gutter. | Cobble basins. | Drive drain. | Brick head walls. | Drainage system (total). |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Cu. yds.* | *Lin. ft.* | *Lin. ft.* | *Lin. ft.* | *Lin. ft.* | *Cu. yds.* | *Sq. yds.* | *No.* | *Lin. ft.* | *Cu. yds.* | |
| Quantity | [1] 35.83 | [2] 323 | 420 | 200 | 100 | 33.96 | 66 | 2 | 146 | 15.87 | |
| Labor | $221.55 | $177.57 | $219.79 | $25.62 | $66.28 | $149.00 | $89.48 | $75.16 | $50.15 | $220.08 | $1,294.68 |
| Material | [3] 150.00 | [4] 292.29 | 71.09 | | | [3] 100.00 | 3.12 | 5.80 | ([5]) | 135.60 | 724.62 |
| Total | 371.55 | 469.86 | 290.88 | 25.62 | 66.28 | 249.00 | 92.60 | 80.96 | 50.15 | 355.68 | 2,052.58 |
| Unit cost | 10.37 | 1.45 | .69 | .128 | .663 | 7.30 | 1.40 | 40.48 | .343 | 22.41 | |

[1] Includes retaining wall of 5.63 cubic yards of concrete.

[2] Includes 103 feet of vitrified pipe repaired and relaid, labor on the same $29.12, included above.

[3] Estimated.

[4] Of this amount $137.95 was for material bought and not used on Mount Vernon Avenue, and $10.44 for separate lengths of vitrified clay pipe.

[5] Furnished by the county.

### TABLE 11.—*Cost data for incidentals.*

| Items. | Superintendence. | Equipment. | Extra work. | Guard rail.[1] | Waste bitumen.[2] | Bound stones. | Miscellaneous. | W. & O. D. pass. | Total. |
|---|---|---|---|---|---|---|---|---|---|
| Labor | $290.10 | | $172.09 | $262.06 | | $18.53 | [3] $8.00 | $335.64 | $1,086.42 |
| Materials | | | 8.75 | 543.29 | $266.08 | 6.56 | | | 824.68 |
| Rent and insurance | 500.00 | [4] $670.00 | | | | | | | 1,170.00 |
| Total | 790.10 | 670.00 | 180.84 | 805.35 | 266.08 | 25.09 | 8.00 | 335.64 | 3,081.10 |

[1] 4,519 linear feet at 17.7 cents each.

[2] Includes 20 barrels left on road, lost by overturned barrels burned, and material adhering to staves (estimated 1 per cent) and used to dip posts.

[3] Storing extra posts.

[4] Includes rent of roller, $30, also depreciation on roller, heating kettles, and small tools.

### TABLE 12.—*Cost data for foundation course.*

| Items. | Gravel in pit. | Loosening and loading. | Hauling. | Spreading. | Rolling. | Foundation complete (total). |
|---|---|---|---|---|---|---|
| | *Tons.* | *Tons.* | *Tons.* | *Sq. yds.* | *Sq. yds.* | *Sq. yds.* |
| Quantity | 5,604.4 | 5,604.4 | 5,604.4 | 15,487.7 | 15,487.7 | 15,487.7 |
| Labor | | $528.58 | $1,453.30 | $470.84 | $47.74 | $2,500.46 |
| Materials | $324.10 | 45.00 | | | 15.49 | 384.59 |
| Total | 324.10 | 573.58 | 1,453.30 | 470.84 | 63.23 | 2,885.05 |
| Cost per square yard | .0209 | .0370 | .0938 | .0304 | .00408 | .1863 |

TABLE 13.—*Cost data for surfacing.*

| Item. | Stone on work. | Spreading stone. | Bitumen on work. | Application of bitumen. | Rolling. | Surface complete. |
|---|---|---|---|---|---|---|
| | *Tons.* | *Tons.* | *Gals.* | *Sq. yds.* | *Sq. yds.* | *Sq. yds.* |
| Quantity | 2,177.39 | 2,177.39 | 31,197.17 | 15,287.7 | 15,287.7 | 15,287.7 |
| Labor | $1,065.10 | $215.81 | $100.74 | $259.13 | $47.57 | $1,688.35 |
| Materials | 2,833.67 | ............ | 2,543.17 | ............ | 18.11 | 5,394.95 |
| Total | 3,898.77 | 215.81 | 2,643.91 | 259.13 | 65.68 | 7,083.30 |
| Unit cost | $1.790 | $0.099 | $0.0847 | $0.017 | $0.0043 | $0.463 |

TABLE 14.—*Total costs.*

| Item. | Quantity. | Cost. | Unit cost. | Per cent of total. |
|---|---|---|---|---|
| | *Sq. yds.* | | | |
| Subgrade | 15,627.5 | $5,911.50 | $0.38 | 28.1 |
| Drainage | ............ | 2,052.58 | ............ | 9.8 |
| Gravel foundation | 15,487.6 | 2,885.05 | .19 | 13.7 |
| Surfacing | 15,287.7 | 7,083.30 | .46 | 33.7 |
| Incidentals | ............ | 3,081.10 | ............ | 14.7 |
| Total | ............ | 21,013.53 | ............ | 100 |

TABLE 15.—*Total materials and cost data per square yard for the different experiments.*

| Experiment No. | Location. | Description. |  |  |  |  | Quantity of material. |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Stone. | Bitumen. |  | Length of section. | Area of section. | Gravel or stone. | Pea gravel or stone chips. | Bituminous material. |
|  |  |  | First application. | Second application. |  |  |  |  |  |
|  |  |  |  |  | *Feet.* | *Sq. yds.* | *Tons.* | *Tons.* | *Gallons.* |
| 1 | Station 1+81 to Station 17+81 | Trap rock | W. G. tar ref | W. G. tar ref | 1,600 | 2,844.40 | 324.23 | 70.07 | 6,243.25 |
| 2 | Station 17+81 to Station 35+91 | Trap rock | W. G. tar ref | Oil asphalt | 1,810 | 3,217.78 | 336.96 | 79.30 | Pen. 5,238.55<br>Seal 1,991.0 |
| 3 | Station 35+91 to Station 54+55 | Trap rock | C. T. ref | C. T. ref | 1,864 | 3,313.78 | 337.86 | 81.66 | Pen 6,477.4<br>Seal 4,518.3 |
| 4 | Station 54+55 to Station 72+55 | Trap | C. T. ref | Oil asphalt | 1,800 | 3,234.58 | 364.95 | 78.87 | 2,016.00 |
| 5 | Station 72+55 to Station 77+55 | Washed gravel | W. G. tar ref.[1] | W. G. tar ref | 500 | 888.89 | 93.93 | 46.00 | 1,842.75 |
| 6 | Station 77+55 to Station 82+61 | Washed gravel | Oil asphalt | Oil asphalt | 506 | 899.33 | 93.93 | 25.89 | 1,965.43 |
| 7 and 8 | Station 82+61 to Station 87+61 | Pit gravel | Res. asph. pet | Res. asph. pet | 500 | 888.89 | 210.00 | 33.75 | 904.50 |

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[1] For the first 91 feet 30 per cent of sand was added to the tar.

COST PER SQUARE YARD (CENTS).

| Experiment No. | Stone on siding. | Unloading stone. | Hauling stone. | Spreading stone. | Chips on siding. | Unloading chips. | Hauling chips. | Spreading chips. | Bitumen on siding | Hauling bitumen. | Loading and heating bitumen. | Applying bitumen. | Rolling penetration stone. | Rolling penetration and seal coat. | Total cost. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15.955 | 2.645 | 1.122 | 0.916 | 4.064 | 0.728 | 0.310 | 0.419 | 17.67 | 0.659 | 0.664 | 1.035 | 0.324 | 0.089 | 46.605 |
| 2 | 15.965 | 2.646 | 2.249 | .913 | 4.066 | .730 | .620 | .420 | 18.20 | .660 | .664 | 1.035 | .325 | .089 | 48.594 |
| 3 | 15.963 | 2.647 | 3.373 | .913 | 4.056 | .730 | .930 | .419 | 15.72 | .638 | .664 | .999 | .314 | .089 | 47.551 |
| 4 | 15.795 | 2.618 | 4.055 | .904 | 4.023 | .722 | 1.118 | .415 | 16.40 | .654 | .657 | 1.023 | .322 | .088 | 48.782 |
| 5 | 11.740 | .416 | 3.763 | .695 | 1.616 | .337 | 1.710 | .349 | 16.68 | .660 | .665 | 1.035 | .472 | .061 | 40.209 |
| 6 | 11.604 | .400 | 3.719 | .743 | 3.199 | .183 | .958 | .289 | 18.60 | .660 | .662 | 1.032 | .467 | .073 | 42.580 |
| 7 and 8 | 4.137 | 2.733 | 5.955 | 3.085 | 2.936 | .674 | 1.393 | .251 | 9.88 | .660 | .665 | 1.035 | .306 | .141 | 33.745 |

TABLE 16.—*Total costs.*

| Experiment No. | Stone on siding. | Unloading stone. | Hauling stone. | Spreading stone. | Chips on siding. | Unloading chips. | Hauling chips. | Spreading chips. |
|---|---|---|---|---|---|---|---|---|
| 1 | $453.92 | $75.25 | $31.94 | $25.96 | $115.61 | $20.75 | $8.81 | $11.92 |
| 2 | 513.75 | 85.18 | 72.36 | 29.39 | 130.85 | 23.48 | 19.95 | 13.50 |
| 3 | 529.00 | 87.72 | 111.78 | 30.26 | 134.74 | 24.18 | 30.81 | 13.90 |
| 4 | 510.93 | 84.72 | 131.15 | 29.23 | 130.14 | 23.35 | 36.16 | 13.42 |
| 5 | 104.36 | 3.70 | 33.45 | 6.18 | 14.37 | 3.00 | 15.20 | 3.10 |
| 6 | 104.36 | 3.70 | 33.45 | 6.68 | 28.77 | 1.65 | 8.62 | 2.60 |
| 7 and 8 | 36.77 | 24.30 | 52.94 | 27.43 | [1] 26.10 | [1] 6.00 | [1] 11.50 | [1] 2.24 |
| Total | 2,253.09 | 364.57 | 467.07 | 155.13 | 580.58 | 102.41 | 131.05 | 60.68 |

[1] Add sand.

| Experiment No. | Bitumen on siding. | Hauling bitumen. | Loading and heating. | Applying bitumen. | Rolling | | Total. |
|---|---|---|---|---|---|---|---|
| | | | | | Penetration stone. | Penetration and seal coat. | |
| 1 | $502.58 | $18.79 | $18.90 | $29.45 | $9.24 | $2.54 | $1,325.66 |
| 2 | 585.96 | 21.25 | 21.36 | 33.31 | 10.46 | 2.88 | 1,563.68 |
| 3 | 521.44 | 21.89 | 22.01 | 34.28 | 10.76 | 2.97 | 1,575.74 |
| 4 | 530.05 | 21.14 | 21.25 | 33.10 | 10.40 | 2.86 | 1,577.90 |
| 5 | 148.34 | 5.87 | 5.91 | 9.20 | 4.20 | .54 | 357.42 |
| 6 | 167.07 | 5.93 | 5.96 | 9.29 | 4.20 | .66 | 382.94 |
| 7 and 8 | 87.73 | 5.87 | 5.91 | 9.20 | 2.72 | 1.25 | 299.96 |
| Total | 2,543.17 | 100.74 | 101.30 | 157.83 | 51.98 | 13.70 | 7,083.30 |

## PRICES OF LABOR AND MATERIALS.

The above cost data are based upon the following unit costs for labor and materials (f. o. b. nearest siding):

Common labor, per day, $1.50 to $1.75.
Skilled labor, per day, $1.75 to $2.25.
Teams, per day, $4.00 to $4.50.
Foreman, per day, $2.25 to $4.00.
Carpenters, per day, $2.50 to $5.00.
Roller man, per month, $65.00 to $70.00.
Superintendent, per month, $125.00.
Trap rock, f. o. b. siding:
  1½ inch, per ton, $1.40.
  Chips, per ton, $1.65.
Gravel, pit-run, per ton, $0.067.
Gravel, pea, per cubic yard, $1.50.
Tar, per gallon, $0.0805.
Oil asphalt exp. Nos. 2 and 4, per gallon, $0.0825.
Residual asphaltic petroleum, per gallon, $0.097.
Oil asphalt exp. No. 6, per gallon, $0.085.
Cement, per barrel, $1.65.
Washed gravel (concrete), per ton, $0.75.
Sand, per ton, $0.55.
Lumber, per M, $25.00.
Reinforcing steel, per pound, $0.03.
Coal, per ton, delivered, $4.00 to $5.00.
Cast iron pipe, 16-inch, per foot, $1.35.
Corrugated metal pipe:
  15-inch, per foot, $0.67.
  18-inch, per foot, $0.783.

Additional items of depreciation, repair, interest and rental on equipment, etc.:

Penetration equipment, $300.00.
Roller, $250.00.
Wagons, $50.00.
Plows, small tools, $70.00.
Bond, insurance, superintendence, transportation and travel, general office, $790.00.

TABLE 17.—*Volume and character of traffic on Russell Road.*

[This table gives the results of traffic counts taken before and after improvement of the road.

| | | Average before improvement.[1] | | Average after improvement.[2] | | | |
|---|---|---|---|---|---|---|---|
| | | | | Maximum. | | Average. | |
| | | North-bound. | South-bound. | North-bound. | South-bound. | North-bound. | South-bound. |
| 1 | Loaded 1-horse wagon | 8 | 9 | 1 | 2 | .......... | 1 |
| 2 | Unloaded 1-horse wagon | 1 | 0 | 3 | 2 | 1 | 1 |
| 3 | Loaded 2-horse wagon | 3 | 4 | 1 | 2 | .......... | .......... |
| 4 | Unloaded 2-horse wagon | 1 | 1 | 3 | 1 | .......... | .......... |
| 5 | Loaded 4-horse wagon | 0 | 0 | 0 | 1 | .......... | .......... |
| 6 | Unloaded 4-horse wagon | 1 | 0 | 8 | 8 | 1 | 1 |
| 7 | One-horse pleasure vehicle | 10 | 10 | 2 | 1 | .......... | .......... |
| 8 | Two-horse pleasure vehicle | 2 | 2 | 1 | 1 | .......... | .......... |
| 9 | Rubber-tired horse vehicle | 0 | 0 | 1 | 1 | .......... | .......... |
| 10 | Saddle horse | 2 | 0 | 96 | 1 | 1 | .......... |
| 11 | Motor cycle | 6 | 6 | 8 | 8 | 1 | 3 |
| 12 | Excessively heavy vehicle | 0 | 0 | .......... | .......... | .......... | .......... |
| 13 | Motor runabout | 0 | 0 | 72 | 75 | 11 | 10 |
| 14 | Motor touring car | 55 | 52 | 271 | 266 | 107 | 107 |
| 15 | Loaded motor dray | 2 | 2 | 2 | 6 | 2 | 3 |
| 16 | Unloaded motor dray | 1 | 1 | 6 | 7 | 2 | 2 |

[1] Average of seven days in June, 1915.

[2] August 3 to December 24, 1916.

## SUMMARY OF EXPERIMENTS ON THE RUSSELL ROAD.

The following report describes the condition of the experiments when inspected on January 11, 1917.

### EXPERIMENT NO. 1.—BITUMINOUS MACADAM, REFINED WATER-GAS TAR.

The surface of this experiment is true and regular, but has a very rough appearance, due to the wearing away of the seal coat. It has raveled slightly in a few places, but is in excellent condition for the application of another seal coat and should have it at the earliest possible date.

### EXPERIMENT NO. 2.—BITUMINOUS MACADAM, REFINED WATER-GAS TAR, OIL ASPHALT SEAL COAT.

This is in practically perfect condition and shows no tendency to ravel or disintegrate. The surface is much smoother than that of No. 1, and offers an interesting comparison between the relative wear of tar and asphalt for a seal coat material.

### EXPERIMENT NO. 3.—BITUMINOUS MACADAM, REFINED COAL TAR.

The general appearance of this surface is between that of experiments Nos. 1 and 2. It shows some tendency to ravel and needs a medium heavy seal coat.

### EXPERIMENT NO. 4.—BITUMINOUS MACADAM, REFINED COAL-TAR, OIL ASPHALT SEAL COAT.

This surface appeared to be intact and satisfactory in every respect at the time of inspection, and was appreciably smoother than that of No. 3.

### EXPERIMENT NO. 5.—BITUMINOUS GRAVEL MACADAM, REFINED WATER-GAS TAR.
### EXPERIMENT NO. 6.—BITUMINOUS GRAVEL MACADAM, OIL-ASPHALT.

There is practically no difference between the two sections at this time, nor is there any evidence of the point where the use of grout was discontinued after a short section had been laid. The surfaces are in excellent condition and show the aggregate throughout, but there is no raveling or displacement.

### EXPERIMENT NO. 7.—GRAVEL, SURFACE TREATED WITH RESIDUAL ASPHALTIC PETROLEUM.

This experiment had a double application. It is rather badly waved from the edges to the quarter points and shows a tendency to form broad, shallow depressions in the wheel tracks. The mat, however, is practically intact and uniform, and except for the waviness along the sides, may be considered in satisfactory condition.

### EXPERIMENT NO. 8.—GRAVEL, SURFACE TREATED WITH RESIDUAL ASPHALTIC PETROLEUM.

This experiment had only one application. It has a few waves, and inequalities of application have left long lean streaks in the surface. At one point slight raveling has started along one of these streaks and the mat is irregular, and, where lean, shows a marked tendency to crumble.

Such expenses as have been incurred for the maintenance of this road will be carried forward and reported in the next progress report.

## EXPERIMENTS ON THE ALEXANDRIA-ACCOTINK ROAD, FAIRFAX COUNTY, VA.

### BITUMINOUS GRAVEL CONCRETE AND EARTH OIL-ASPHALT.

This experimental project is located on the Alexandria-Accotink Road, in Fairfax County, Va. It begins at the south end of Hunting Creek Bridge, the corporate limits of the city of Alexandria, and runs in a southerly direction to Gum Spring. The road was improved originally during 1914–15 under the post-road act of August, 1912. It was surfaced to a width of 14 feet with gravel, the compacted depth of which was 7 inches. The maximum grade was 7 per cent.

The old gravel road was reshaped, given a crown of one-fourth inch to 1 foot, and covered with an experimental surfacing. The total length of the road was 25,100 feet. The width surfaced was 14 feet, except at some sharp curves and road intersections, where it was widened. Gravel shoulders were constructed on either side of the finished surface. These were made 4 feet wide in fills and 3 feet in cuts. The thickness of gravel at the edge of the surface was 4 inches.

In addition to the surfacing and shoulders some extra work was done. Guardrail was built from station 57+50 to station 62+00, station 198+00 to station 204+00, and station 248+00 to station 250+00. Several pipe culverts were lengthened and new headwalls built. A new 4 by 4 by 33 foot concrete box culvert was built at station 133+55.

### BITUMINOUS GRAVEL CONCRETE.

Location, station 0+00 to station 217+00.
station 223+00 to station 250+80.
Total length, 24,500 feet.
Total area, 38,442.6 square yards.

The materials for this experiment were:

*Asphalt.*—Oil asphalt; see typical analysis in Table 18.

*Aggregate.*—Crushed and screened gravel from the Ayers pit. Fine aggregate passing ¼-inch circular openings, coarse aggregate passing 1¼-inch and retained on ¼-inch circular openings. Fine aggregate contained less than 5 per cent of clay.

*Limestone dust.*—Ordinary ground limestone used as filler.

*Pea gravel.*—Washed Potomac River gravel, screened through ½-inch and over ¼-inch screen. Used as top-dressing for seal coat.

The mixing plant was of the stationary type, operated by steam power. The gravel was excavated by hand, run through a jaw crusher, and screened to remove tailings before it was heated. The heating was done in two rotary drums, wood being used as fuel. The fine and coarse aggregates then were separated by means of a ¼-inch screen and stored in two bins immediately over the mixer. The asphalt was heated in two kettles supplied with steam coils, and the mixing was done in an ordinary twin pug mixer. The average time for mixing a batch was 1 minute. Table 19 shows analyses of several samples of mix taken at the plant. Table 20 shows similar analyses of road samples of mix.

Most of the hauling was done with 1-ton autotrucks, which carried three batches of the hot mix at a load. On the longest haul distances several two-horse wagons carrying four batches to a load were used to supplement the trucks.

The hot mix was dumped from the trucks or wagons onto a steel dumping board and spread with hand shovels and asphalt rakes. Then it was "set" by rolling with a 2½-ton tandem roller and compacted to its final shape with an 8-ton tandem roller. The loose depth of the hot mix averaged about 2¾ inches, and the compacted depth was not less than 2 inches. The temperature at which the material was spread ranged from 200° to 300° F.

The seal coat was of the same asphalt used in the mix, covered with pea gravel. The asphalt was spread at a temperature of about 350° F., about one-third gallon per square yard being used. The pea gravel was spread at the rate of about 1 cubic yard to 150 square yards of surface. After the gravel was spread the surface was rolled with the 8-ton tandem roller.

### EARTH-OIL ASPHALT EXPERIMENT.

Location, station 217+00 to station 223+00.
Total length, 600 feet.
Total area, 934.8 square yards.

The experiment was based upon laboratory investigations which in May resulted in the construction of a 50-foot section of earth-asphalt on the Arlington Farm of the Department of Agriculture. The section selected was a part of an earth road, the soil of which was largely fine clay. About 2 inches of this material was removed from the surface and the section was brought to a uniform grade and cross-section and rolled with a 2-ton tandem roller. The excavated material was hauled to a local paving plant, mixed with water and hot oil asphalt to form a mixture of proper consistency, which was deposited in a layer about 3 inches thick on the earth subgrade above described. The mixture in this case was too stiff to be handled satisfactorily with rakes and too soft to be rolled. It was shaped in the best manner possible with shovel backs and allowed to dry out. The surface hardened rapidly, with the formation of numerous contraction cracks. These were filled with a thin grout of the same mixture used in the surface, and the section was opened to traffic. It remained in excellent condition throughout the summer and autumn, although the contiguous earth road was almost impassable at times in wet weather. At about the time freezing weather set in traffic was cut off the section in order to make some drain connections. It soon was observed that the soil-asphalt surface began to crack, owing probably to the effect of frost action on the underlying subgrade, and in a short time complete disintegration extended from the sides toward the center.

The materials used in the longer experiment about to be described were a very homogeneous clay soil, asphalt, and water. The properties of the soil and asphalt are shown in Tables 21 and 18, respectively.

The mixing was done at the same plant used for mixing the bituminous gravel concrete, but in an entirely different manner. The soil was measured first into the mixer just as it came from the bank. Water was admixed to form a rather sloppy mud, after which the hot asphalt was added and the mixing was continued until a uniform gray color was produced. The temperature of the asphalt was about 250° F., but the temperature of the fresh mixture was only slightly higher than that of the air. The proportions of the mixture were such that each batch contained approximately 560 pounds of earth, 100 pounds of asphalt, and 25 to 30 gallons of water. Results of analyses of the mixture show an actual percentage of asphalt of 14.68.

TABLE 18.—*Analyses of asphalts.*

| | Experiment. | |
|---|---|---|
| | Bituminous gravel concrete. | Clay asphalt. |
| Specific gravity 25°/25° C. | 1.041 | 1.035 |
| Melting point °C. | 54.5 | 55 |
| Penetration at 25° C., 100 grams, 5 sec. | 64 | 101 |
| Loss, 5 hours, 163° C., 20 grams ... per cent | .28 | .42 |
| Penetration of residue, as above | 42 | 57 |
| Per cent of total bitumen insoluble in 86° B naphtha | 29.48 | 27.09 |
| Fixed carbon ... per cent | 18.88 | 17.03 |
| Soluble in $CS_2$ (total bitumen) ... do | 99.45 | 99.86 |
| Organic matter, insoluble ... do | .16 | .10 |
| Inorganic matter, insoluble ... do | .39 | .04 |
| Total ... do | 100.00 | 100.00 |

TABLE 19.—*Tests of bituminous concrete (plant samples).*

| | Sample having maximum bitumen. | Sample having minimum bitumen. | Sample having maximum coarse aggregate. | Sample having minimum coarse aggregate. | Average of 61 samples. |
|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Bitumen | 8.5 | 5.2 | 5.4 | 7.0 | 6.5 |
| Aggregate retained on ¼-inch screen | 48.4 | 59.0 | 68.3 | 34.1 | 54.5 |
| Passing ¼ inch screen and retained on 200-mesh sieve | 38.5 | 34.3 | 23.3 | 55.2 | 35.8 |
| Passing 200-mesh sieve | 4.6 | 1.5 | 3.0 | 3.7 | 3.2 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

TABLE 20.—*Tests of bituminous concrete (road samples).*

| | Sample having maximum bitumen. | Sample having minimum bitumen. | Sample having maximum coarse aggregate. | Sample having minimum coarse aggregate. | Average of 42 samples. |
|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Bitumen | 8.8 | 4.0 | 5.1 | 8.5 | 6.4 |
| Aggregate retained on ¼-inch screen | 52.9 | 62.8 | 66.8 | 46.5 | 54.5 |
| Passing ¼-inch screen and retained on 200-mesh sieve | 35.8 | 31.3 | 25.7 | 41.6 | 36.1 |
| Passing 200-mesh sieve | 2.5 | 1.9 | 2.4 | 3.4 | 3.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

TABLE 21.—*Mechanical analysis of earth.*

| | Per cent. |
|---|---|
| Passing ¼-inch screen, retained on 10-mesh sieve | 0.4 |
| Passing 10-mesh sieve, retained on 20-mesh sieve | 1.0 |
| Passing 20-mesh sieve, retained on 30-mesh sieve | 2.0 |
| Passing 30-mesh sieve, retained on 40-mesh sieve | 3.0 |
| Passing 40-mesh sieve, retained on 50-mesh sieve | 3.0 |
| Passing 50-mesh sieve, retained on 80-mesh sieve | 4.8 |
| Passing 80-mesh sieve, retained on 100-mesh sieve | 2.2 |
| Passing 100-mesh sieve, retained on 200-mesh sieve | 4.6 |
| Passing 200-mesh sieve | 79.0 |
| | 100.0 |

## SUMMARY OF COST DATA.

The cost data for the experiments described above are presented in Tables 22 to 24.

TABLE 22.—*Quantities and costs of materials.*

| Item. | Quantity in work unit. | Kind of material. | Quantity of material. | Unit cost. |  | Total cost. | Remarks. |
|---|---|---|---|---|---|---|---|
|  |  |  |  | Material unit. | Work unit. |  |  |
|  |  |  |  |  | *Cents.* |  |  |
| Foundation repairs. | 39,377.4 square yards. | Gravel (run-of-pit). | 150 cubic yards. | $0.05 | 0.019 | $7.50 | Estimated. |
| Shoulders | 50,160 linear feet. | do | 2,500 cubic yards. | .05 | .25 | 125.00 | Do. |
| Surface, bituminous gravel concrete. | 38,442.6 square yards. | Gravel | 3,500 cubic yards. | .10 | .91 | 350.00 | Do. |
|  |  | Asphalt | 380.66 tons | 15.00 | 14.59 | 5,609.90 | As billed. |
|  |  | Limestone dust | 98 tons | 6.00 | 1.53 | 588.00 | Do. |
|  |  | Pea gravel for seal coat. | 365 tons | 1.50 | 1.42 | 547.50 | Do. |
| Surface, earth oil-asphalt. | 934.8 square yards. | Earth | 85 cubic yards. | .10 | .90 | 8.50 | Do. |
|  |  | Asphalt | 14.35 tons | 15.00 | 23.02 | 215.25 | Do. |
| Extra work |  | All materials |  |  |  | 514.67 |  |

TABLE 23.—*Labor cost.*

| Item. | Quantity. | Operation. | Labor costs. | Unit labor costs. |
|---|---|---|---|---|
|  |  |  |  | *Cents.* |
| Foundation | 39,377.4 square yards | Shaping | $1,758.46 | 4.467 |
|  |  | Sprinkling | 175.50 | .445 |
|  |  | Rolling | 310.31 | .787 |
|  |  |  | 2,244.27 | 5.699 |
| Bituminous gravel concrete surface. | 38,442.6 square yards | Hauling asphalt | 547.75 | 1.424 |
|  |  | Mixing | 5,826.62 | 15.156 |
|  |  | Hauling mix | 2,553.06 | 6.640 |
|  |  | Setting headers | 546.94 | 1.421 |
|  |  | Spreading mix | 1,394.37 | 3.627 |
|  |  | Rolling | 295.81 | .765 |
|  |  | Sealing | 506.50 | 1.315 |
|  |  | Hauling pea gravel | 299.26 | .777 |
|  |  |  | 11,970.31 | 31.125 |
| Earth oil-asphalt surface | 934.8 square yards | Mixing | 231.75 | 24.79 |
|  |  | Hauling | 105.25 | 11.26 |
|  |  | Setting headers | 9.00 | .96 |
|  |  | Spreading | 83.56 | 8.93 |
|  |  |  | 429.56 | 45.94 |
| Gravel shoulders | 50,160 linear feet | Loosening and loading | 888.84 | 1.772 |
|  |  | Hauling | 1,310.06 | 2.611 |
|  |  | Spreading | 953.15 | 1.899 |
|  |  | Rolling | 16.00 | .031 |
|  |  |  | 3,168.05 | 6.313 |

TABLE 24.—*Summary of material and labor costs.*

| Item. | Quantity in working unit. | Total cost. | Cost per work unit. |
|---|---|---|---|
| Foundation: | | | *Cents.* |
| Material | 39,377.4 square yards | $7.50 | 0.019 |
| Labor | | 2,244.28 | 5.699 |
| Total | | | 5.718 |
| Shoulders: | | | |
| Material | 50,160 linear feet | 125.00 | .25 |
| Labor | | 3,168.05 | 6.31 |
| Total | | | 6.56 |
| Surface: | | | |
| Bituminous concrete material | 38,442.6 square yards | 7,095.40 | 18.45 |
| Labor | | 11,970.31 | 31.13 |
| Total | | | 49.58 |
| Surface: | | | |
| Earth oil-asphalt material | 934.8 square yards | 223.75 | 23.92 |
| Labor | | 429.56 | 45.95 |
| Total | | | 69.87 |
| Incidental expense | | 7,000.00 | |
| Extra work | | 1,230.10 | |
| Total cost | | 33,493.95 | |

The above cost data are based on the following unit prices of labor:

| | | |
|---|---|---|
| Foremen | per day of 8 hours | $4.00 |
| Rollermen and skilled laborers | do | 4.00 |
| Laborers | per day | 1.60–2.40 |
| Trucks | per hour | 1.00 |
| Teams | per day | 4.50 |

## SUMMARY OF EXPERIMENTS ON ALEXANDRIA-ACCOTINK ROAD.

The following describes the condition of the above experiments when inspected on January 11, 1917.

### EXPERIMENT NO. 1.—BITUMINOUS GRAVEL CONCRETE.

The surface of this experiment is practically in perfect condition. Difficulty has been found already with the rutting of the right-hand shoulder going down steep grades, but at the time of inspection there was no indication that the edge of the surfacing had begun to shear.

### EXPERIMENT NO. 2.—EARTH OIL ASPHALT.

This section never had an opportunity to dry out thoroughly, since freezing weather came on the day following its completion. During thaws it was kept in shape for some time with a road grader and small tandem roller, but at the time of inspection was rather badly rutted and broken through to the gravel foundation in two places.

## EXPERIMENTS ON THE GUM SPRING-MOUNT VERNON ROAD, FAIRFAX COUNTY, VA.

### BITUMINOUS SURFACE TREATMENT ON A NEW GRAVEL ROAD.

The Mount Vernon Road extends from Gum Spring, in a southerly direction, 2.05 miles to the Mount Vernon estate, and is wholly in

Fairfax County. This road had been reconstructed and surfaced with gravel only a few months before the experimental surface treatment was undertaken. The principal features of the road may be described briefly as follows:

| | |
|---|---|
| Total width of road | 24 feet. |
| Total width of gravel surface | 16 feet. |
| Compacted depth of gravel (2 courses having respective depths of 3 and 5 inches) | 8 inches. |
| Crown of road | ½ inch to 1 foot. |
| Maximum grade | 5 per cent. |
| Drainage conditions | Favorable. |

Gravel for use in the original construction was obtained from the county pit, located about 500 feet south of station 0+00 at Gum Spring, and the Walker pit, located about 100 feet east of station 92+50. The gravel from the county pit was used from station 0+00 to station 48+00, while that from the Walker pit was used from station 48+00 to the south end of the road. The mechanical analysis for the material from each pit is shown in Tables 25 and 26.

TABLE 25.—*Mechanical analysis of sand-clay gravel from Walker pit, Fairfax County, Va.*

| Totals retained. | | Passing— | Retained on— | Per cent of sample. | Per cent of coarse aggregate. | Per cent of fine aggregate. |
|---|---|---|---|---|---|---|
| | *Per cent.* | | | | | |
| ¾-inch screen | 6.5 | 1-inch screen | ¾-inch screen | 6.5 | 21.4 | |
| ½-inch screen | 15.9 | ¾-inch screen | ½-inch screen | 9.4 | 30.9 | |
| ¼-inch screen | 30.4 | ½-inch screen | ¼-inch screen | 14.5 | 47.7 | |
| 10-mesh sieve | 40.6 | ¼-inch screen | 10-mesh sieve | 10.2 | | 14.7 |
| 20-mesh sieve | 45.5 | 10-mesh sieve | 20-mesh sieve | 4.9 | | 7.0 |
| 30-mesh sieve | 59.2 | 20-mesh sieve | 30-mesh sieve | 13.7 | | 19.7 |
| 40-mesh sieve | 77.2 | 30-mesh sieve | 40-mesh sieve | 18.0 | | 25.9 |
| 50-mesh sieve | 85.3 | 40-mesh sieve | 50-mesh sieve | 8.1 | | 11.6 |
| 80-mesh sieve | 88.4 | 50-mesh sieve | 80-mesh sieve | 3.1 | | 4.5 |
| 100-mesh sieve | 88.9 | 80-mesh sieve | 100-mesh sieve | .5 | | .7 |
| 200-mesh sieve | 89.6 | 100-mesh sieve | 200-mesh sieve | .7 | | 1.0 |
| | | 200-mesh sieve | | 10.4 | | 14.9 |
| | | | | 100.0 | 100.0 | 100.0 |

TABLE 26.—*Mechanical analysis of sand-clay gravel from county pit.*

| Totals retained. | | Passing— | Retained on— | Per cent of sample. | Per cent of coarse aggregate. | Per cent of fine aggregate. |
|---|---|---|---|---|---|---|
| | *Per cent.* | | | | | |
| 1-inch screen | 4.8 | 1¼-inch screen | 1-inch screen | 4.8 | 8.6 | |
| ¾-inch screen | 15.6 | 1-inch screen | ¾-inch screen | 10.8 | 19.3 | |
| ½-inch screen | 34.6 | ¾-inch screen | ½-inch screen | 19.0 | 34.0 | |
| ¼-inch screen | 55.9 | ½-inch screen | ¼-inch screen | 21.3 | 38.1 | |
| 10-mesh sieve | 69.9 | ¼-inch screen | 10-mesh sieve | 14.0 | | 31.7 |
| 20-mesh sieve | 74.5 | 10-mesh sieve | 20-mesh sieve | 4.6 | | 10.4 |
| 30-mesh sieve | 80.3 | 20-mesh sieve | 30-mesh sieve | 5.8 | | 13.2 |
| 40-mesh sieve | 86.5 | 30-mesh sieve | 40-mesh sieve | 6.2 | | 14.1 |
| 50-mesh sieve | 88.6 | 40-mesh sieve | 50-mesh sieve | 2.1 | | 4.8 |
| 80-mesh sieve | 91.1 | 50-mesh sieve | 80-mesh sieve | 2.5 | | 5.7 |
| 100-mesh sieve | 92.0 | 80-mesh sieve | 100-mesh sieve | .9 | | 2.0 |
| 200-mesh sieve | 93.7 | 100-mesh sieve | 200-mesh sieve | 1.3 | | 2.9 |
| | | 200-mesh sieve | | 6.7 | | 15.2 |
| | | | | 100.0 | 100.0 | 100.0 |

The traffic over this road varies considerably from season to season and has not yet been studied in detail. It consists for the most part of tourist automobiles going to and from Mount Vernon, which accounts for the extreme variability. It is planned to make periodic counts of the traffic, and to publish the results in future progress reports.

The purpose of the experiments was to gain information regarding the results to be obtained by using certain bituminous materials in the surface treatment of gravel roads. Three different materials were used, and the road was divided into three sections, according to the kind of bituminous material in the surface. Section 1 extends from station 0+00 to station 23+55; section 2 from station 23+55 to station 85+45, and section 3 from station 85+45 to station 109+00. Before taking up the description of the experiments separately, the data common to all three will be stated briefly.

The work was done by contract between November 3 and December 5, 1916, during which time there were only 15 weather working days. The contract prices are given in the latter part of this report.

In all of the experiments the road first was swept clean with a horse-drawn rotary broom, followed by men with push brooms. The bituminous material was applied under pressure of about 15 pounds per square inch by means of a motor truck distributor of a capacity of 1,200 gallons. The spray line of the distributor was 8 feet long and covered one-half the width of the road at a trip.

The top-dressing for all of the surface treatments was obtained from the Walker gravel pit and consisted of pit-run gravel from which the coarser particles had been screened out. The screening was done by hand, and the screen used had approximately 1-inch opening and was inclined at an angle of about 45°. As shown by the mechanical analysis of this material, given in Table 25, comparatively few particles passed the screen that would not pass a ½-inch mesh laboratory screen. The gravel top-dressing was hauled out in a 5-ton automobile truck and distributed in piles about 30 feet apart along the road. The spreading was done by hand.

### EXPERIMENT NO. 1.—SURFACE TREATMENT WITH COAL-TAR PREPARATION, APPLIED COLD.

Location, station 0+00 to station 23+55.
Total length, 2,355 feet.
Total area, 4,187 square yards.

The tar used in this experiment was hauled from Washington in the auto distributor, and applied at the average rate of 0.49 gallon per square yard. Table 27 shows the analysis of the tar. The temperature of the material at the time it was applied was about 150° F.

TABLE 27.—*Analysis of coal-tar preparation*[1] *used on experiment No. 1 and for first application on experiment No. 3.*

| | | |
|---|---|---|
| Specific gravity, 25°/25° C | 1.145 | |
| Specific viscosity, Engler, 40° C., 50 c. c | 14.4 | |
| Per cent free carbon | 6.24 | |
| Distillation: | | |
| | Per cent by volume. | Per cent by weight. |
| Water | 0.0 | 0.0 |
| First light oils (110° C.) | 0.4 | 0.3 |
| Second light oils (110–170° C.) | 1.7 | 1.0 |
| Heavy oils (170°–270° C.) | 24.6 | 21.1 |
| Heavy oils (270°–300° C.) | 9.2 | 8.0 |
| Pitch residue | 64.1 | 69.6 |
| Total | 100.0 | 100.0 |

It had been planned to allow the tar to stand for several hours after it had been applied to the road before covering it with the gravel top-dressing, but the tendency of the material to run off the road was so great that it was found necessary to cover it immediately after the distributor had finished applications. The gravel was spread at a fairly uniform rate of 1 cubic yard to 78 square yards of surface.

The only noticeable lack of uniformity in the workmanship on this experiment is where the cut-off valve of the distributor failed to work properly on a return trip, with the result that a double application of tar was made on the west half of the road from station 13 + 50 to station 15 + 00. It also was necessary, of course, to increase the amount of gravel top-dressing on this part of the experiment.

### EXPERIMENT NO. 2.—SURFACE TREATMENT WITH ASPHALTIC OIL, APPLIED HOT, AND CLAY GRAVEL.

Location, station 23+55 to 85+45.
Total length, 6,140 feet.
(Equality station decreases length of section 50 feet.)
Total area, 10,915 square yards.

The bituminous material used in this experiment was shipped to Alexandria in tank cars. At the Alexandria siding the oil was heated and pumped into the auto distributor, in which it was hauled 7 miles to the road. The material was heated to a temperature of about 200° F. and there was no appreciable loss of temperature during the haul. The analysis of the oil is shown in Table 28.

---

[1] Fairly thin fluid.

TABLE 28.—*Analysis of residual asphaltic petroleum*[1] *used on experiment No. 2.*

| | |
|---|---|
| Specific gravity, 25°/25° C | 0.995 |
| Specific viscosity, Engler, 100° C., 50 c. c | 17.5 |
| Float test, 50° C. (seconds) | 36 |
| Loss, 163° C., 5 hours, 20 grams, (per cent) | 13.56 |
| Float test on residue, 50° C. (seconds) | 232 |
| Per cent of total bitumen insoluble in 86° B naphtha | 20.12 |
| Fixed carbon (per cent) | 10.79 |
| Soluble in $CS_2$ (total bitumen per cent) | 99.87 |
| Organic matter insoluble (per cent) | .11 |
| Inorganic matter insoluble (per cent) | .02 |
| Total | 100.00 |

The first tank car of oil delivered at Alexandria was found to be low in viscosity and was rejected as not conforming to the specification. This rejection occasioned a delay of about two weeks in securing the oil for experiment No. 2, during which time experiment No. 3 was completed. When the contractor was ready to resume work on experiment No. 2, bad weather had set in and further delay was occasioned. Finally, it was deemed expedient to complete the experiment, although the weather conditions were not altogether favorable, because it was feared that long-continued bad weather might make it necessary to postpone the work until the next season. The oil accordingly was applied on the first warm day, regardless of the fact that the road surface was damp. The oil was applied 0.53 gallon per square yard, while the rate for gravel top-dressing was the same as in experiment No. 1, or 78 square yards to 1 cubic yard. No lack of uniformity in the distribution of either the oil or the gravel was noticed. Where successive distributor loads of oil joined, care was exercised to prevent overlapping, and there was no unevenness at any of the joints. From station 85+00 to 85+45, however, the gravel surface on the east side of the road was not very well bonded when the work was done.

### EXPERIMENT NO. 3.—SURFACE TREATMENT USING TWO APPLICATIONS OF TAR.

First application of coal-tar preparation applied cold; second application refined coal tar, applied hot.

Location, station 85+45 to 109+00.
Total length, 2,355 feet.
Total area, 4,187 square yards.

Both kinds of tar for this experiment were hauled in the distributor from Washington, about 15 miles, to the road. The first application was of the same material as used on experiment No. 1, analysis of which is shown in Table 27. This application was made in a manner similar to that employed on experiment No. 1, except that the rate at which the tar was applied was only 0.35 gallon per square yard, and only sufficient gravel top-dressing was used to prevent the wheels of the distributor from picking up the surface while making the second application. Two days were allowed to elapse between the first and second applications.

---

[1] Viscous, sticky fluid.

TABLE 29.—*Analysis of refined coal tar* [1] *used on experiment No. 3, second application.*

| | | |
|---|---|---|
| Specific gravity, 25°/25° C | | 1.207 |
| Float test, 32° C. (seconds) | | 117 |
| Per cent free carbon | | 11.02 |
| Distillation: | | |
| | Per cent by volume. | Per cent by weight. |
| Water | 0.0 | 0.0 |
| First light oils (110° C.) | 0.0 | 0.0 |
| Second light oils (110–170° C.) | 0.0 | 0.0 |
| Heavy oils (170–235° C.) | 5.0 | 3.9 |
| Heavy oils (235–270° C.) | 12.2 | 10.2 |
| Heavy oils (270–300° C.) | 7.6 | 6.4 |
| Pitch residue | 75.2 | 79.5 |
| Total | 100.0 | 100.0 |

The tar for the second application is represented by the analysis shown in Table 29. This material was heated at the plant in Georgetown, so that when it reached the work the temperature was about 205° to 220° F. It was spread at the average rate of 0.50 gallon per square yard. Immediately after the second application of tar the surface was covered with the gravel top-dressing, spread at the rate of 1 cubic yard to about 78 square yards of surface. The amount of top-dressing required for the two applications was 1 cubic yard of gravel to 53.7 square yards of surface.

The places where a noticeable lack of uniformity occurred in the work are:

(1) In making the first application the distributor moved too slowly on the east side of the road from station 98+50 to 100+00 and the tar was applied over this area at the rate of about one-half gallon to the square yard.

(2) In making the second application an excess of tar was deposited at station 85+45, where experiments 2 and 3 join.

(3) The second application was made in cold weather and the tar chilled so that little of the gravel top-dressing sank into it. Later, when the road was opened to traffic, it was observed that much of the top-dressing had been swept off the road surface by passing vehicles.

---

[1] Sticky, very viscous.

(4) The work on this experiment was delayed because of bad weather, but the old road surface was uniformly in fairly good condition when the work was done.

*Cost data.*

The bid prices were based on furnishing and placing the materials by the material unit and were as follows:

| | |
|---|---|
| 1. Light coal-tar preparation in place, per gallon | $0.16 |
| 2. Heavier coal-tar preparation in place, per gallon | .16 |
| 3. Asphaltic oil in place, per gallon | .17 |
| 4. Gravel for top-dressing in place, per cubic yard | 1.05 |

At the above unit prices the costs per square yard for the different experiments were:

| | Cents. |
|---|---|
| For experiment No. 1 (cold tar) | 9.18 |
| For experiment No. 2 (residual asphaltic petroleum) | 10.32 |
| For experiment No. 3 (2 applications of tar—1 cold, 1 hot) | 15.26 |

Total contract price for the three experiments, $2,149.57.

During the progress of the work, and with the cooperation of the contractor, a record was kept of both the labor employed and materials used. Tables 30 and 31 show an itemized summary of the costs to the contractor, which are based on the following scale of unit costs:

| | |
|---|---|
| Foreman, per hour | $0.50 |
| Laborers, per hour | .25 |
| Helper on truck distributor, per hour | .30 |
| Driver for truck distributor, per hour | .40 |
| Auto truck for hauling gravel (including driver and supplies), per hour | 2.00 |
| Auto truck distributor (including driver and supples), per hour | 3.00 |
| Boiler for heating asphaltic oil (including fireman and supplies) per hour | 1.00 |

TABLE 30.—*Cost data for excavating, screening, and hauling gravel for top-dressing.*

| Item. | Quantity. | Total cost. | Unit cost, per cubic yard. |
|---|---|---|---|
| | *Cubic yards.* | | |
| Loosening gravel | 271 | $56.50 | $0.2085 |
| Screening gravel | 271 | 53.50 | .1974 |
| Loading and dumping gravel | 271 | 46.00 | .1697 |
| Hauling gravel[1] | 271 | 184.00 | .6789 |
| Stripping pit | 271 | 4.00 | .0147 |
| Gravel in pit | 271 | 13.55 | .05 |
| Total | 271 | 357.55 | 1.3192 |

[1] Average haul for gravel, 3,900 feet. The high cost of hauling is due to the use of an auto truck that could be kept running but a small portion of the time.

TABLE 31.—*Contractor's cost of surface treating Mount Vernon experimental road, by experiments.*

| Item. | Experiment No. 1. | | | Experiment No. 2. | | | Experiment No. 3. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Quantity. | Cost. | Cost per square yard. | Quantity. | Cost. | Cost per square yard. | Quantity. | Cost. | Cost per square yard. |
| | | | *Cents.* | | | *Cents.* | | | *Cents.* |
| General expenses. | .............. | $28.00 | 0.669 | .............. | $39.20 | 0.359 | .............. | $90.40 | 2.159 |
| Sweeping road | 4,187 square yards. | 7.00 | .167 | 10,915 square yards. | 18.00 | .165 | 4,187 square yards. | 20.00 | .478 |
| Distributing oil or tar. | 2,048 gallons.. | 52.80 | 1.261 | 5,766 gallons.. | 108.00 | .989 | 3,557 gallons.. | 128.80 | 3.076 |
| Heating oil... | .............. | ...... | ........ | 5,766 gallons.. | 88.00 | .806 | .............. | ...... | ........ |
| Spreading gravel. | 54 cubic yards | 14.00 | .334 | 139 cubic yards. | 65.20 | .598 | 78 cubic yards | 34.00 | .812 |
| Oil or tar...... | 2,048 gallons, at 8½ cents. | 174.08 | 4.157 | 5,766 gallons, at 8 cents. | 461.28 | 4.226 | 1,482 gallons, at 8½ cents.<br>2,075 gallons, at 8½ cents. | 125.97<br>176.38 | 3.009<br>4.212 |
| Gravel........ | 54 cubic yards | 71.23 | 1.701 | 139 cubic yards. | 183.37 | 1.680 | 78 cubic yards | 102.90 | 2.457 |
| Total... | .............. | 347.11 | 8.289 | .............. | 963.05 | 8.823 | .............. | 678.45 | 16.203 |

### SUMMARY OF EXPERIMENTS ON GUM SPRING-MOUNT VERNON ROAD, FAIRFAX COUNTY, VA.

The following report describes the condition of the above experiments when inspected on January 11, 1917:

#### EXPERIMENT NO. 1.—COAL-TAR PREPARATION.

The surface is breaking rapidly and becoming mealy, particularly up the grade at the beginning of the experiment. There is no well-formed mat; deterioration during the 10 days preceding inspection was noticeably rapid.

#### EXPERIMENT NO. 2.—RESIDUAL ASPHALTIC PETROLEUM.

The surface has a very uniform mat for short distances, alternating with areas which have become badly rutted. The rutting has occurred both in cut and in fill, and in at least two places the red clay subgrade has worked through the gravel.

#### EXPERIMENT NO. 3.—COAL-TAR PREPARATION AND COAL TAR REFINED.

This experiment shows a fairly intact surface, with a rather well-formed mat. It has only two or three small areas with any ruts whatever, and is not badly rutted anywhere.

## EXPERIMENTS WITH PIPE CULVERTS OF CORRUGATED METAL ON THE TEXAS POST ROAD IN COMAL AND HAYS COUNTIES, TEX.

### GALVANIZED AND UNGALVANIZED PIPE MADE OF VARIOUS KINDS OF IRON AND STEEL.

These experiments are for the purpose of comparing the behavior of different kinds of iron and steel when used in corrugated pipe culverts under the conditions prevailing in Comal and Hays Counties, Tex. All of the culverts were placed in the spring and summer of 1915 and were in perfect condition when placed. They are reported on at this time in order to describe their condition when inspected in March, 1917.

The pipe used was all 24 inches in diameter and made of 14 gauge (U. S. standard) metal. Both galvanized and ungalvanized sheets were used. The culvert structures are all provided with concrete head walls and include from one to four lines of pipe. Table 32 gives the number, location, and a brief description for each culvert. In all cases the structure numbers are indented in the tops of the head walls. The engineer's stationing, used in fixing the locations, is as follows:

*In Hays County.*—Station numbers increase southward from 1,357 at the Blanco River to station 1986, Hays-Comal County line. In Comal County the station numbers decrease southward from 539 + 16 (=station 1986, Hays County survey), at the Hays-Comal County line to 0 at the north city limits of New Braunfels, and increase southward from 539 + 16 at the south city limits of New Braunfels to 1045 + 27 at the Comal-Guadalupe County line.

Tables 33 and 34 show the results of laboratory analyses of samples taken from the galvanized and ungalvanized pipe, respectively. The samples in all cases were 4-inch by 6-inch rectangles, and were cut before the pipes were placed.

Table 35 records the condition of the various pipes when inspected in March, 1917.

TABLE NO. 32.—*Locations of experimental culverts, Texas post road.*

| Landmarks and culvert No. | Station No. | Number lines of pipe. | Description of culverts or landmarks. |
|---|---|---|---|
| Hays County | 1357 | | South bank of Blanco River. |
| No. 62 | 1419 | 1 | Ungalvanized Bessemer steel. |
| No. 65 | 1457+50 | 1 | Galvanized Bessemer steel. |
| No. 68 | 1515 | 1 | Do. |
| San Marcos | 1584 | | North city limits, San Marcos River. |
| | 1675 | | South city limits, San Marcos River. |
| No. 74 | 1748+70 | 1 | Galvanized open-hearth steel. |
| No. 75 | 1765+35 | 1 | Ungalvanized Bessemer steel. |
| County line | 1986 | | Hays County survey. |
| | 539+16 | | Comal County survey. |
| No. 94. I. & G. N. R. R. crossing, | 508 | 1 | Galvanized copper-bearing open-hearth steel. |
| No. 97 | 476+10 | 1 | Ungalvanized copper-bearing iron. |
| No. 98 | 466+60 | 1 | Ungalvanized copper-bearing steel. |
| No. 101 | 393+85 | 1 | Galvanized copper-bearing steel. |
| No. 103. Under concrete crossing, | 355+00 | 1 | Ungalvanized ingot iron. |
| No. 109 | 168 | 4 | North, galvanized Bessemer steel.<br>North center, ungalvanized open-hearth steel.<br>South center, galvanized open-hearth steel.<br>South, ungalvanized Bessemer steel. |
| No. 110 | 112+50 | 2 | North, galvanized open-hearth steel.<br>South, ungalvanized open-hearth steel. |
| New Braunfels | 0 | | North city limits, Guadalupe River. |
| | 539+16 | | South city limits. |
| No. 127 | 716 | 2 | North, galvanized ingot iron.<br>South, galvanized copper-bearing iron. |
| No. 128 | 726 | 2 | North, ungalvanized copper-bearing iron.<br>South, galvanized copper-bearing iron. |
| No. 131 | 777 | 2 | North, ungalvanized open-hearth steel.<br>South, ungalvanized copper-bearing open-hearth steel. |
| Railroad crossing | 791 | | M. K. & T. R. R. |
| No. 134 | 815 | 1 | Galvanized ingot iron. |
| No. 143 | 937 | 4 | North, galvanized copper-bearing open-hearth steel.<br>North center, galvanized copper-bearing iron.<br>South center, ungalvanized copper-bearing iron.<br>South, ungalvanized copper-bearing open-hearth steel |
| No. 148 | 1012 | 1 | Ungalvanized ingot iron. |
| No. 149 | 1018 | 2 | North, galvanized ingot iron.<br>South, ungalvanized ingot iron. |
| County line | 1045+27 | | Comal, Guadalupe Counties. |

TABLE No. 33.—*Tests on galvanized metal used in experimental corrugated culverts on Texas post road.*

| Metal. | Structure No. | Spelter per square foot of metal. | Analysis of base metal. | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Carbon. | Sulphur. | Phosphorus. | Manganese. | Copper. | Silicon. |
| | | *Ounces.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* | *Per ct.* |
| Galvanized Bessemer steel | 109 | 2.97 | 0.11 | 0.052 | 0.098 | 0.34 | 0.00 | 0.005 |
| Do | 65 | 2.59 | .09 | .047 | .107 | .36 | .004 | ........ |
| Do | 68 | 2.80 | .10 | .053 | .104 | .37 | .002 | ........ |
| Galvanized open-hearth steel | 109 | 2.74 | .09 | .043 | .013 | .41 | Trace. | ........ |
| Do | 110 | 2.58 | .10 | .049 | .017 | .40 | .008 | ........ |
| Do | 74 | 2.84 | .09 | .037 | .037 | .39 | .003 | ........ |
| Galvanized copper-bearing steel | 94 | 2.48 | .07 | .033 | .0095 | .32 | .12 | ........ |
| Do | 101 | 2.59 | .07 | .036 | .0095 | .41 | .20 | ........ |
| Do | 143 | 2.48 | .08 | .048 | .0095 | .42 | .22 | ........ |
| Galvanized copper-bearing iron | 127 | 1.90 | .04 | .039 | .012 | .056 | .12 | ........ |
| Do | 128 | 1.86 | .05 | .040 | .0095 | .056 | .13 | ........ |
| Do | 143 | 2.02 | .04 | .034 | .0074 | .050 | .12 | ........ |
| Galvanized ingot iron | 127 | 2.44 | .04 | .044 | .0063 | .019 | .06 | ........ |
| Do | 134 | 2.41 | .03 | .035 | .0074 | .050 | .04 | ........ |
| Do | 149 | 2.50 | .03 | .045 | .0063 | .019 | Trace. | ........ |

TABLE No. 34.—*Tests on ungalvanized metal used in experimental corrugated culverts on Texas post road.*

| Metal. | Structure No. | Analysis of metal. | | | | | |
|---|---|---|---|---|---|---|---|
| | | Carbon. | Sulphur. | Phosphorus. | Manganese. | Copper. | Silicon. |
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Bessemer steel | 109 | 0.12 | 0.057 | 0.097 | 0.34 | 0.000 | .......... |
| Do | 62 | .10 | .045 | .099 | .37 | .004 | .......... |
| Do | 75 | .10 | .049 | .096 | .37 | .004 | .......... |
| Open-hearth steel | 109 | .09 | .042 | .014 | .36 | Trace. | 0.005 |
| Do | 110 | .08 | .040 | .017 | .26 | .004 | .......... |
| Do | 131 | .08 | .048 | .012 | .38 | .04 | .......... |
| Copper-bearing steel | 98 | .07 | .032 | .0084 | .32 | .22 | .015 |
| Do | 131 | .09 | .057 | .013 | .43 | .15 | .......... |
| Do | 143 | .08 | .057 | .012 | .43 | .22 | .......... |
| Copper-bearing iron | 97 | .04 | .036 | .0084 | .043 | .12 | .01 |
| Do | 128 | .05 | .040 | .0095 | .056 | .12 | .......... |
| Do | 143 | .04 | .035 | .012 | .019 | .12 | .......... |
| Ingot iron | 103 | .02 | .022 | .0053 | .028 | .006 | .00 |
| Do | 148 | .03 | .032 | .0074 | .028 | .016 | .......... |
| Do | 149 | .03 | .027 | .0053 | .028 | .012 | .......... |

TABLE 35.—*Condition Record March, 1917.*

| Metal. | Structure No. | Location. | Position. | Condition, March, 1917. |
|---|---|---|---|---|
| | | *Station.* | | |
| Galvanized Bessemer steel | 109 | 168+00 | North | In apparently new condition. No deterioration of spelter, and entire absence of scale or rust. |
| Do | 65 | 1457+50 | ................ | Do. |
| Do | 68 | 1515 | ................ | Do. |
| Galvanized open-hearth steel | 109 | 168+00 | South center | Do. |
| Do | 110 | 112+50 | North | Do. |
| Do | 74 | 1748+70 | ................ | Do. |
| Galvanized copper-bearing steel | 94 | 508 | ................ | Do. |
| Do | 101 | 393+85 | ................ | Do. |
| Do | 143 | 937+00 | North | Do. |
| Galvanized copper-beraing iron | 127 | 716+00 | South | Do. |
| Do | 128 | 726+00 | do | Do. |
| Do | 143 | 937+00 | North center | Do. |
| Galvanized ingot iron | 127 | 716+00 | North | Do. |
| Do | 134 | 815+00 | North | Do. |
| Do | 149 | 1018+00 | North | Do. |

TABLE 35.—*Condition Record, March, 1917*—Continued.

| Metal. | Structure No. | Location. | Position. | Condition, March, 1917. |
|---|---|---|---|---|
| | | *Station.* | | |
| Ungalvanized Bessemer steel.... | 109 | 168+00 | South......... | Considerably rusted and starting to scale slightly. Rust removed with effort, and deterioration of metal noted to a small extent on scaled spots. |
| Do......................... | 62 | 1419 | ............... | Slight coating of rust, easily removed. No scale or deterioration of metal noted. |
| Do......................... | 75 | 1765+35 | ............... | Do. |
| Ungalvanized open-hearth steel.. | 109 | 168+00 | North center.. | Slight coating of rust, easily dusted off. No scale or deterioration of metal noted. |
| Do......................... | 110 | 112+50 | South......... | Considerably rusted and starting to scale slightly. Rust removed with difficulty, and deterioration of metal noted to a small extent on scaled spots. |
| Do......................... | 131 | 777+00 | North......... | Considerably rusted. Coating removed only with effort. No scaling or deterioration of metal noted. |
| Ungalvanized copper-bearing steel. | 98 | 466+60 | ............... | Slight coating of rust easily dusted off. No scale or deterioration of metal. |
| Do......................... | 131 | 777+00 | South......... | Considerably rusted. Coating removed only with effort. No scaling or deterioration of metal noted. |
| Do......................... | 143 | 937+00 | .....do........ | Considerably rusted. Coating easily removed. No scaling or deterioration of metal noted. |
| Ungalvanized copper-bearing iron. | 97 | 476+10 | ............... | Slight coating of rust, easily dusted off. No scale or deterioration of metal noted. |
| Do......................... | 128 | 726+00 | North......... | Do. |
| Do......................... | 143 | 937+00 | South center.. | Considerably rusted. Coating easily removed. No scaling or deterioration of metal noted. |
| Ungalvanized ingot iron.......... | 103 | 355+00 | Under concrete crossing. | Considerably rusted and starting to scale slightly. Rust removed with effort, and deterioration of metal noted to a small extent on scaled spots. |
| Do......................... | 148 | 1012+00 | ............... | Considerably rusted. Coating of rust easily removed. No scaling or deterioration of metal noted. |
| Do......................... | 149 | 1018+00 | South......... | Considerably rusted. Coating removed only with effort. No scale or deterioration of metal noted, but certain few spots indicate early formation of scale. |

## SUPPLEMENTARY REPORTS OF EXPERIMENTS PREVIOUSLY REPORTED.

The following reports are in continuation of others already published by the department in the annual "Progress Reports of Experiments in Dust Prevention and Road Preservation." It was decided to abandon the experiments at Ames, Iowa, and Knoxville, Tenn., but the histories of these experiments as well as of several others are summarized with the supplementary reports, so that the results obtained may be studied conveniently by those interested. In all cases references are made to the earlier publications in which reports regarding the various projects have appeared.

## MOUNT VERNON AVENUE, ALEXANDRIA COUNTY, VA., 1915.

### BITUMINOUS MACADAM, BITUMINOUS CONCRETE, BITUMINOUS GRAVEL CONCRETE.

These experimental sections were constructed on Mount Vernon Avenue beginning at the Military Road near Arlington Cemetery and extending to Washington Avenue; thence to Washington Street, to the city line of Alexandria. The original report, giving details of materials and methods of construction, is published in Bulletin No. 407, United States Department of Agriculture. In addition, it may be stated that experiments Nos. 1 and 2, and 5 to 10, inclusive, bled profusely with the first warm weather of the spring of 1916, and required the prompt application of torpedo sand to prevent picking up under traffic.

The work was inspected on January 11, 1917, and the condition of the experimental sections at that time was as follows:

*Experiment No. 1—Bituminous macadam, sandstone with fluxed native asphalt A; experiment No. 2—Bituminous macadam, sandstone with oil-asphalt X.*—There was no marked difference in the appearance of these experiments. They were in excellent condition, with the seal coat still almost intact, particularly on experiment No. 1, the bitumen having bled up to form a close, generally uniform surface. Experiment No. 2 appeared to have more of the coarse stone exposed. Only two or three patches have been made since construction.

*Experiment No. 3—Bituminous concrete, sandstone with fluxed native asphalt A; experiment No. 4—Bituminous concrete, sandstone with oil-asphalt X.*—In January, 1916, about 6 months after completion, it was noticed that large areas in both of these experiments became covered with check cracks, generally in two directions—longitudinally and at right angles to traffic. From 24 to 48 hours after the appearance of these cracks the areas would begin to ravel, and, once broken, disintegration would follow rapidly. Temporary repairs were provided for at once and only a few of the cracked areas actually broke. Those which raveled were dug out carefully and filled with penetration patches until, in March, it was possible to apply a general seal coat to both experiments. A fluid, refined water-gas tar was used and the covering material was torpedo sand. The characteristics of the bituminous material are given in Table 36, and the cost data and quantities will be found in Table 38.

TABLE 36.—*Analysis of refined water-gas tar.*

| | | |
|---|---|---|
| Specific gravity 25° C/25° C. | | 1.145 |
| Specific viscosity, Engler, 50° C. 50 c. c. | | [1] 26.5 |
| Bitumen soluble in $CS_2$ (total bitumen) | per cent.. | 98.92 |
| Organic matter insoluble (free carbon) | do.... | 1.05 |
| Inorganic matter insoluble | do.... | 0.03 |
| | | 100.00 |

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[1] Average of three samples.

TABLE 36.—*Analysis of refined water-gas tar*—Continued.

| Distillation: | Character. | Per cent by volume. | Per cent by weight. |
|---|---|---|---|
| Water |  | 0.0 | 0.0 |
| First light oils (110° C.) |  | 0.0 | 0.0 |
| Second light oils (−110°–170° C.) | Clear. | Trace. | Trace. |
| Heavy oils (170°–270° C.) | 2/25 solid | 28.0 | 24.5 |
| Heavy oils (270°–300° C.) | Clear. | 10.3 | 9.0 |
| Pitch | Sticky; semisolid. | 61.7 | 66.5 |
|  |  | 100.0 | 100.0 |

This treatment prevented further deterioration, although experiment No. 4 has a somewhat distorted cross section at points where the heavy sidehill fill has settled. At the time of inspection both of these experiments presented a practically uniform appearance. The surface was intact, although the seal coat was blotchy, some areas were black and leathery where fat areas had been caused by the penetration patches in the original surface, and other places were brown and mosaic in texture.

*Experiment No. 5—Bituminous macadam, gneiss with fluxed native asphalt A; experiment No. 6—Bituminous macadam, gneiss with oil-asphalt X.*—These experiments were somewhat open and porous in the spring of 1916, but at the time of inspection were in good condition, having sealed themselves satisfactorily. To prevent raveling, a few patches had to be made early in the year before warm weather caused bitumen to bleed to the surface. The seal coat is now fairly uniform, although several mosaic areas were noted, and the surface is somewhat rough, owing to irregularities from construction rather than to wear.

*Experiment No. 7—Bituminous concrete, gneiss with oil-asphalt X; experiment No. 8—Bituminous concrete, gneiss with fluxed native asphalt A.*—These experiments were somewhat smoother than experiments Nos. 5 and 6. Not having been so open in the spring of 1916, the bleeding above referred to produced a more uniform mat, and the surface was in good condition, except for slight irregularities.

*Experiment No. 9—Bituminous gravel concrete, pit-run gravel with oil-asphalt Y.*—This experiment was somewhat rough and uneven, owing to irregularities apparently due to lack of uniformity in the seal coat; otherwise the experiment was in good condition. Only one or two small areas raveled in the spring of 1916, but were repaired easily.

*Experiment No. 10—Bituminous gravel concrete, pit-run gravel with fluxed native asphalt B.*—This was the poorest of the gravel sections. A considerable total area, almost all being on the Four Mile Run fill, required patching early in 1916, and practically the entire surface received a seal coat in intermittent applications. The mixing plant used in construction stood at approximate station 95 and much of the construction work south of Hume Spring was done after the surface of experiment 10 was laid. On account of the dripping of the bitumen from the mix as it was hauled over the section, a blotchy, irregular seal coat characterized this experiment. This blotchy effect was practically all worked out of the surface by careful maintenance, although it still was full of slight, short irregularities. On the whole, the experiment was in better condition than during the spring and early summer of 1916.

*Experiment No. 11—Bituminous gravel concrete, pit-run gravel with refined tar.*—This experiment had a browner, more open appearance than any other gravel section. It had to be slightly patched in the summer of 1916, but at the time of inspection was intact and in good condition, except for slight irregularities due to construction.

*Experiment No. 12—Bituminous gravel concrete, pit-run gravel with oil-asphalt Y.*—This experiment, especially the part between the railroad crossing, was much the best of the gravel sections. It had an even, regular, somewhat leathery mat, and was practically free from irregularities. At the crest of the grade between the railroads a spring broke through the road during the early summer and a stone drain had to be laid. Except for repairs at this place, the surface required very little attention. Only one spot showed bad wear, and that was at Hume Station, where the mixed work joins the brick crossing.

*Experiment No. 13—Bituminous macadam, trap rock with oil-asphalt X; Experiment No. 14, bituminous macadam, trap rock with fluxed native asphalt A.*—These experiments were very open and porous at the time of completion, and one or two small patches had to be made to prevent raveling. The binder bled up satisfactorily, and at the time of inspection the surfaces presented no apparent difference and were intact and in good condition.

*Experiment No. 15—Bituminous concrete, trap rock with fluxed native asphalt A; Experiment No. 16, Bituminous concrete, trap rock with oil-asphalt X.*—Within 4 months after completion these experiments began to ravel badly and experiment No. 16 failed over 60 per cent of its area. As the failure occurred during the winter months, it was impossible to make proper bituminous patches, so repairs were made by removing the old surface where disintegrated and filling the holes with a good sand-clay gravel and allowing it to compact under traffic. These areas were fairly smooth by spring and then were treated with a heavy seal of cold water-gas tar or coal-tar patching material and covered with ⅝-inch gravel. At the time of inspection both sections were in good condition, although slightly rough in some places. The largest breaks in the original surface occurred on the fill at approximate station 191, and although a sharp turn occurs at station 192, the repairs made appear to have been adequate.

*Experiment No. 17—Bituminous macadam, granite with fluxed native asphalt; experiment No. 18, Bituminous macadam, granite with oil-asphalt X.*—In the spring of 1916 small areas, distributed quite generally over the surface of both experiments, began to disintegrate so that numerous penetration patches were necessary. These sections had been laid over old macadam which was scarified and dressed with a layer of new stone before the penetration course was applied. The breaking of the newly constructed surface appeared to be due to movement in the wearing surface caused by the failure to fill and bond the new stone added to the foundation. Both sections were in good condition for retreatment and this was applied. The characteristics of the bituminous material used in the reseal are given in Table 37 and the cost data and quantities will be found in Table 38.

TABLE 37.—*Analyses of residual asphaltic petroleum.*[1]

| | |
|---|---|
| General characteristics, viscous, sticky fluid. | |
| Specific gravity 25° C./25° C | A—0.991<br>B—0.989 |
| Flash point ° C. | 100 |
| Burning point ° C. | 120 |
| Float test 50° C. (seconds) | A—30<br>B—30 |
| Viscosity Engler 50 c. c. at 100° C., specific | 14.2 |
| Loss at 163° C., 5 hours, 20 grams, per cent. | 14.30 |
| Character of residue very viscous, sticky. | |
| Float test on residue 50° C. (seconds) | 160 |
| Per cent of total bitumen insoluble in 86° B., naphtha | 17.39 |
| Per cent of fixed carbon | 10.44 |
| Bitumen soluble in $CS_2$ (total bitumen), per cent | 99.89 |
| Organic matter insoluble, per cent | 0.11 |
| Inorganic matter insoluble, per cent | 0.00 |
| | 100.00 |

*Experiment No. 19—Bituminous concrete, granite with oil-asphalt X.*—This experiment showed marked deterioration and many penetration patches had to be made in the spring of 1916. It was brought into good condition for treatment and a new seal coat applied in May and June, 1916. The same bituminous material was used as on experiments Nos. 17 and 18, and cost data and quantities are given in Table 38. At the time of inspection this experiment showed a few wavy spots due to fat penetration patches under the retreatment; otherwise the experiment was in good condition.

*Experiment No. 20—Bituminous concrete, granite with fluxed native asphalt A.*—Except at the south end, this experiment did not disintegrate so noticeably as the other three granite sections. It was placed in good condition with penetration patches and received a surface treatment in May. The same bituminous material was used as for the treatment on experiments Nos. 17, 18, and 19, and cost data and quantities are given in Table 38. At the time of inspection this experiment was in almost perfect condition.

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[1] Samples A and B from each of 2 barrels, except where indicated tests were made on composite sample.

*Corrugated metal culverts.*—The corrugated metal culverts on the Mount Vernon Avenue experimental road were inspected at the same time as the road surface, and were found to be in good, sound condition. There was no appreciable difference in the amount of rusting, although all were covered with a thin layer of rust. In the case of the coppered-iron and ingot-iron culverts this rust seemed to be somewhat more easily rubbed off than in the case of the others, leaving smooth black metal exposed. The rust in the open-hearth steel culverts appeared to be of a more scaly nature than in the others.

Table 40 shows a traffic census record for the entire project, and Table 39 the maintenance cost record for the calendar year. The cost figures in Table 39 include the cost of surface retreatments given in Table 38.

TABLE 38.—*Material and cost data of re-treatments in 1916 on Mount Vernon Avenue.*[1]

| Experiment No. | Bituminous material. | Date of treatment. | Area of experiment. | Quantity of material per square yard. | | | Cost per square yard. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Bituminous material. | Gravel. | Sand. | Bituminous material. | Gravel. | Sand. | Cleaning surface. | Applying bituminous material. | Applying sand or gravel. | Supervision. | Total. |
| | | 1916. | *Sq. yds.* | *Gal.* | *Cu. yds.* | *Cu. yds.* | *Cent.* | *Cent.* | *Cent.* | *Cent.* | *Cent.* | *Cent.* | *Cent.* | *Cent.* |
| 3 | Water-gas tar, refined | Mar. 7-8 | 1,867.8 | 0.419 | | 0.0161 | 03.36 | | 03.55 | 00.21 | 00.17 | 00.13 | 00.80 | 08.49 |
| 4 | do | Mar. 9-11 | 1,924 | .408 | | .0156 | 03.26 | | 02.49 | 00.17 | 00.17 | 00.13 | 01.03 | 07.26 |
| 17 | Res. asph. petroleum | June 8-12 | 1,422 | .342 | 0.0163 | | 03.14 | 05.09 | | 00.23 | 01.12 | 00.30 | 01.05 | 10.93 |
| 18 | do | June 3-7 | 1,580 | .346 | .0163 | | 03.16 | 04.66 | | 00.34 | 00.64 | 00.21 | 00.88 | 09.89 |
| 19 | do | May 29-June 2 | 1,728 | .348 | .0165 | | 03.18 | 04.29 | | 00.19 | 00.64 | 00.25 | 00.72 | 09.27 |
| 20 | do | May 25-28 | 1,867 | .335 | .0162 | | 03.05 | 04.47 | | 00.16 | 00.39 | 00.15 | 00.70 | 08.96 |

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[1] These costs are included in the maintenance given in Table 39.

TABLE 39.—*Surface maintenance costs of 1915 experiments on Mount Vernon Avenue, Alexandria, Va., from Jan. 1 to Dec. 31, 1916.*

| Experiment No. | Area. | Cost per square yard. | | | Experiment No. | Area. | Cost per square yard. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Construction. | Maintenance. | Total. | | | Construction. | Maintenance. | Total. |
| | Sq. yds. | Cents. | Cents. | Cents. | | Sq. yds. | Cents. | Cents. | Cents. |
| 1 | 1,202.22 | 80.13 | 7.36 | 87.49 | 10 | 5,445.22 | 43.74 | 2.10 | 45.84 |
| 2 | 2,599.67 | 66.43 | 2.08 | 68.51 | 11 | 1,573.34 | 41.62 | 2.42 | 44.04 |
| 3 | 1,867.78 | 88.98 | 11.90 | 100.88 | 13 | 1,688.88 | 48.41 | .92 | 49.33 |
| 4 | 1,924.00 | 74.27 | 10.06 | 84.33 | 14 | 1,777.78 | 58.98 | 1.61 | 60.59 |
| 5 | 2,196.56 | 47.74 | 2.95 | 50.69 | 15 | 1,742.22 | 65.77 | .18 | 65.95 |
| 6 | 1,422.22 | 36.85 | .52 | 37.37 | 16 | 1,621.34 | 52.66 | 3.24 | 55.90 |
| 7 | 2,369.78 | 45.57 | .89 | 46.46 | 17 | 1,422.22 | 63.04 | 14.02 | 77.06 |
| 8 | 1,221.33 | 57.81 | 1.41 | 59.22 | 18 | 1,580.45 | 48.29 | 14.57 | 62.86 |
| 9<br>12 | 6,863.22 | 33.54 | 2.94 | 36.48 | 19 | 1,728.00 | 54.26 | 11.95 | 66.21 |
| | | | | | 20 | 1,866.67 | 67.73 | 10.59 | 78.32 |

TABLE 40.—*Volume and character of traffic during a 16-hour period on Mount Vernon Avenue, Apr. 8 to Dec. 24, 1916.*

| | | North of Russell Road. | | | | South of Russell Road. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum. | | Average. | | Maximum. | | Average. | |
| | | Northbound. | Southbound. | Northbound. | Southbound. | Northbound. | Southbound. | Northbound. | Southbound. |
| 1 | Loaded 1-horse wagon | 2 | 3 | ........ | 1 | 2 | 2 | ........ | 1 |
| 2 | Unloaded 1-horse wagon | 5 | 7 | 1 | 1 | 4 | 6 | 1 | 1 |
| 3 | Loaded 2-horse wagon | 2 | 6 | ........ | ........ | 2 | 4 | ........ | 1 |
| 4 | Unloaded 2-horse wagon | 4 | 2 | 1 | 1 | 4 | 2 | 1 | ........ |
| 5 | Loaded 4-horse wagon | 3 | 1 | ........ | ........ | 1 | 1 | ........ | ........ |
| 6 | Unloaded 4-horse wagon | 1 | ........ | ........ | ........ | 2 | ........ | ........ | ........ |
| 7 | 1-horse pleasure vehicle | 7 | 7 | 2 | 3 | 7 | 7 | 2 | 2 |
| 8 | 2-horse pleasure vehicle | 1 | 1 | ........ | ........ | 1 | 2 | ........ | ........ |
| 9 | Rubber-tired horse vehicle | ........ | 1 | ........ | ........ | 1 | 1 | ........ | ........ |
| 10 | Saddle horse | 96 | 8 | 5 | 1 | 3 | 6 | 1 | 1 |
| 11 | Motor cycle | 25 | 32 | 7 | 9 | 24 | 32 | 5 | 6 |
| 12 | Excessively heavy vehicle [1] | 1 | 3 | ........ | ........ | 1 | 3 | ........ | ........ |
| 13 | Motor runabout | 27 | 20 | 13 | 11 | 17 | 16 | 9 | 9 |
| 14 | Motor touring car | 715 | 720 | 270 | 257 | 451 | 470 | 201 | 190 |
| 15 | Loaded motor dray | 16 | 21 | 6 | 20 | 13 | 17 | 6 | 9 |
| 16 | Unloaded motor dray | 19 | 18 | 6 | 5 | 14 | 11 | 6 | 4 |

[1] Very heavy vehicles, such as carry ore, stone, timber, machinery, etc.

## FALLS ROAD, MONTGOMERY COUNTY, MD., 1915.

### SURFACE TREATMENT ON WATER-BOUND MACADAM (OILS, TAR PREPARATIONS, REFINED TARS).

The original report of these experiments was given in Bulletin No. 407, U. S. Department of Agriculture. The following report describes the condition of the experiments on February 21, 1917.

*Experiment No. 1—Asphaltic petroleum, cold application, corresponding to experiment No. 3 on Rockville Pike.*—This surface shows a tendency to become mealy in cold weather, and with continued wet weather works up into mud. It was seen in the winter of 1915–16 that the road could not be brought safely through another cold season, and a re-treatment was given late in the fall of 1916. The same material was used as for the original application, and its characteristics are given in Table 41. Cost data and quantities appear in Table 43. At the time of inspection the surface showed its characteristic tendency to work into mud, but had behaved much better as a whole than did the corresponding section on the Rockville Pike during a corresponding period after its construction.

TABLE 41.—*Analysis of asphaltic petroleum*[1] *used in re-treatment of experiment No. 1.*

| | | |
|---|---|---|
| Specific gravity 25°/25° C | | 0.956 |
| Flash point (° C) | | 28 |
| Burning point (° C.) | | 50 |
| Specific viscosity, Engler, 25° C., 50 c. c | | 187.5 |
| Loss at 163° C., 5 hours, 20 grams (per cent) | | 28.23 |
| Float test on residue,[2] 50° C. (seconds) | | 188 |
| Per cent of total bitumen insoluble in 86° B. naphtha | | 16.58 |
| Fixed carbon (per cent) | | 9.04 |
| Total bitumen (soluble in $CS_2$) | per cent | 99.95 |
| Organic matter insoluble | per cent | .05 |
| Inorganic matter insoluble | per cent | .00 |
| | | 100.00 |

*Experiment No. 2—Residual asphaltic petroleum, hot application, corresponding to experiment No. 5, on the Rockville Pike.*—This section was in generally good condition. There was a slight tendency to crumble, especially at the edges, but little or no mud formed. It was thought very early in 1916 that this section would require retreatment during the summer, but it bled profusely and had to be dressed heavily until about the middle of the summer. The section appeared to be somewhat better than section No. 5 of the Rockville Pike.

*Experiment No. 3—Coal-tar preparation, cold application.*—The original application on this section never produced a close intact mat and in the summer of 1916 had to be patched frequently where the macadam had become exposed and in November was retreated with the same bituminous material as applied originally. The characteristics of the bituminous material appear in Table 42, and cost data and quantities in Table 43. At the time of inspection the experiment was in excellent condition, with no signs of further disintegration or unusual wear.

TABLE 42.—*Analysis of coal-tar preparation*[3] *used in retreatment of experiment No. 3.*

| | | |
|---|---|---|
| Specific gravity 25°/25° C | | 1.149 |
| Specific viscosity, Engler 50 c. c. at 40° C | | 12.1 |
| Per cent free carbon (insoluble in $CS_2$) | | 6.19 |
| Distillation: | Per cent by volume. | Per cent by weight. |
| Water | 0.0 | 0.0 |
| First light oils[4] (to 110° C.) | 1.8 | 1.1 |
| Second light oils[4] (110° to 170° C.) | 1.5 | .8 |
| Heavy oils[5] (170° to 270° C.) | 19.8 | 17.1 |
| Heavy oils[4] (270° to 300° C.) | 9.0 | 7.8 |
| Pitch residue | 67.9 | 73.2 |
| Total | 100.0 | 100.0 |

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[1] Fairly viscous sticky fluid.
[2] Very viscous sticky fluid.
[3] Fairly thin fluid.
[4] Clear.
[5] One-half solid.

TABLE 43.—*Materials and cost data for surface retreatment in 1916.*

| Item. | Experiment No. 1 (asphaltic petroluem). | Experiment No. 3 (coal-tar preparation). |
|---|---|---|
| Area treated..........square yards.. | 7,625 | 13,235 |
| Quantity of material per square yard: | | |
| Bituminous material..........gallons.. | 0.23 | 0.33 |
| Gravel..........cubic yards.. | ............ | .0115 |
| Sand..........do.... | .0114+ | ............ |
| Cost per square yard (cents): | | |
| Bituminous material.......... | 2.52 | 3.06 |
| Gravel.......... | ............ | 3.45 |
| Sand.......... | 2.51 | ............ |
| Cleaning surface.......... | .10 | .41 |
| Hauling materials.......... | .77 | .14 |
| Applying bituminous materials.......... | .35 | .49 |
| Applying sand or gravel.......... | .18 | .24 |
| Supervision.......... | .35 | .36 |
| Total (cents).......... | 6.78 | 8.15 |

*Experiment No. 4—Refined water-gas tar, cold application, similar to experiment No. 2 on Rockville Pike.*—This section has not shown the initial signs of disintegration characteristic of section 2 of the pike, which is troublesome unless cared for by immediate retreatment. Several intersecting bad roads tended to impair the character of the surface near the intersections owing to the clay that was tracked on the bituminous surface. The experiment was in good condition, but indications were that a second application of tar would be required in the early summer.

*Experiment No. 5—Refined coal tar, hot application, similar to experiment No. 1 on the Rockville Pike.*—This experiment was in generally good condition. It suffered a little near the cemetery, owing to large quantities of mud being brought upon it from side roads and drives. At the time of inspection there was no disintegration.

Following the same procedure used in connection with the other experimental roads, a traffic census was taken on the Falls Road for 15 hours every thirteenth day from April 10 to December 31, 1916. A tabulation of the maximum and average of each class of traffic for this period is given in Table 45. Table 44 shows comparative cost data to December 31, 1916, for the various experiments included in this project. The cost figures in Table 44 include the cost of general retreatments as given in Table 43.

TABLE NO. 44.—*Surface maintenance costs of 1915 experiments on Falls Road, Montgomery County, Md., from January 1 to December 31, 1916.*

| Experiment No. | Length of section. | Area. | Cost per square yard. | | | Maintenance cost per mile of surface. |
|---|---|---|---|---|---|---|
| | | | Construction. | Maintenance. | Total. | |
| | *Feet.* | *Sq. yds.* | *Cents.* | *Cents.* | *Cents.* | |
| 1.......... | 4,575 | 7,625 | 7.77 | 6.25 | 14.02 | $550.00 |
| 2.......... | 4,386 | 7,310 | 12.11 | 1.07 | 13.12 | 94.16 |
| 3.......... | 7,941 | 13,235 | 8.48 | 9.33 | 17.80 | 821.00 |
| 4.......... | 5,718 | 9,530 | 9.63 | .10 | 9.73 | 8.80 |
| 5.......... | 5,880 | 9,800 | 10.21 | .01 | 10.22 | .88 |

TABLE 45.—*Volume and character of traffic on Falls Road, Apr. 10 to Dec. 26, 1916.*

| | | Maximum. | | Average. | |
|---|---|---|---|---|---|
| | | West bound. | East bound. | West bound. | East bound. |
| 1 | Loaded 1-horse wagon | 16 | 6 | 3 | 3 |
| 2 | Unloaded 1-horse wagon | 5 | 12 | 2 | 2 |
| 3 | Loaded 2-horse wagon | 10 | 17 | 3 | 4 |
| 4 | Unloaded 2-horse wagon | 12 | 4 | 3 | 2 |
| 5 | Loaded 4-horse wagon | 11 | 6 | 2 | 2 |
| 6 | Unloaded 4-horse wagon | 4 | 8 | ........ | 1 |
| 7 | 1-horse pleasure vehicle | 115 | 132 | 37 | 38 |
| 8 | 2-horse pleasure vehicle | 4 | 1 | ........ | ........ |
| 9 | Rubber-tired horse vehicle | 3 | 4 | ........ | ........ |
| 10 | Saddle horse | 17 | 13 | 4 | 3 |
| 11 | Motor cycle | 8 | 6 | 1 | 1 |
| 12 | Excessively heavy vehicle[1] | 4 | 4 | ........ | 1 |
| 13 | Motor runabout | 17 | 14 | 7 | 6 |
| 14 | Motor touring car | 82 | 93 | 29 | 29 |
| 15 | Loaded motor dray | 5 | 6 | 2 | 2 |
| 16 | Unloaded motor dray | 2 | 3 | ........ | ........ |

[1] Very heavy vehicles, such as carry ore, stone, timber, machinery, etc.

## BRADLEY LANE, MONTGOMERY COUNTY, MD., 1915.

### BITUMINOUS MACADAM, OIL-ASPHALT.

Description of the original construction of this experiment on Bradley Lane appeared in Bulletin No. 407, U. S. Department of Agriculture. The following report covers maintenance during the last year and the condition of the road in the spring of 1917.

At the time of construction in 1915 this experiment was top-dressed with limestone chips. Owing to the heavy traffic, all excess of this material was ground rapidly to powder and dissipated. In consequence, the wearing course stone became visible over the entire road, and in July, 1916, there was applied a surface treatment using a bituminous material represented by the analysis given in Table 46, and, instead of limestone chips, a hard, water-worn, $\frac{5}{8}$-inch river gravel. The quantities and costs appear in Table 47. The cost of this experiment to December 31, 1916, appears in Table 48. That the cost of maintenance was lower than that of surface treatment is explained by the omission of supervision and of a small distributed hauling charge from the total maintenance figures. The surface required no repairs of any kind and had displayed no weakness, except at one point in front of the first driveway on the south side near the east end of the road. Here a very small area of about 2 square feet showed a few web-like cracks in the spring of 1916. The surface at the time of last inspection was in perfect condition. No distinction has been apparent either in appearance or wear between the plain oil-asphalt macadam and the sand-oil-asphalt grouted macadam, and henceforth the entire road will be considered as a single experiment, reserving necessary comment only for the grouted section. A traffic census has been taken on this experiment, as on the others in Montgomery County, and the results appear in Table 49.

TABLE 46.—*Analysis of residual asphaltic petroleum*[1] *used in surface treatment of Bradley Lane.*

| | |
|---|---|
| Specific gravity, 25°/25° C. | 0.993 |
| Specific viscosity, Engler, 100° C., 50 c. c. | 13.5 |
| Float test at 50° C., seconds | 28 |
| Loss at 163° C., 5 hours, 20 grams, per cent | 13.71 |
| Float test on residue, 50° C., seconds | 151 |
| Per cent of total bitumen insoluble in 86° B. naphtha | 18.63 |
| Per cent fixed carbon | 11.25 |
| Bitumen soluble in $CS_2$ (total bitumen), per cent | 99.89 |
| Organic matter insoluble, per cent | .08 |
| Inorganic matter insoluble, per cent | .03 |
| Total | 100.00 |

TABLE 47.—*Materials and cost data for surface treatment in 1916.*

| | | |
|---|---|---|
| Area treated | square yards | 6,788 |
| Quantity of material per square yard: | | |
| Bituminous material | gallons | 0.195 |
| Gravel | cubic yards | .0113 |
| Cost per square yard (cents): | | |
| Bituminous material | | 2.15 |
| Gravel | | 2.90 |
| Cleaning surface | | .28 |
| Hauling materials | | .82 |
| Applying bituminous materials | | .80 |
| Applying sand and gravel | | .42 |
| Supervision | | .62 |
| Total | | 7.99 |

TABLE 48.—*Surface maintenance costs of 1915 experiments, Bradley Lane, Montgomery County, Md., from Jan. 1 to Dec. 31, 1916.*

| Experiment No. | Length of section. | Area. | Cost per square yard. | | | Maintenance cost per mile. |
|---|---|---|---|---|---|---|
| | | | Construction. | Maintenance. | Total. | |
| | *Feet.* | *Sq. yards.* | *Cents.* | *Cents.* | *Cents.* | |
| 1 | 3,614 | 6,421 | 32.84 | 7.29 | 40.48 | [2] $684.31 |
| 2 | 200 | 367 | 39.42 | | | |

TABLE 49.—*Volume and character of traffic on Bradley Lane, Jan. 1 to Dec. 30, 1916.*

| | | Twenty-four-hour period. | | | |
|---|---|---|---|---|---|
| | | Maximum. | | Average. | |
| | | East bound. | West bound. | East bound. | West bound. |
| 1 | Loaded 1-horse wagon | 11 | 15 | 6 | 7 |
| 2 | Unloaded 2-horse wagon | 12 | 13 | 5 | 4 |
| 3 | Loaded 2-horse wagon | 24 | 14 | 10 | 6 |
| 4 | Unloaded 2-horse wagon | 8 | 18 | 2 | 6 |
| 5 | Loaded 4-horse wagon | 3 | 3 | 1 | 1 |
| 6 | Unloaded 4-horse wagon | 1 | 1 | | |
| 7 | One-horse pleasure vehicle | 11 | 8 | 3 | 4 |
| 8 | Two-horse pleasure vehicle | 1 | 2 | | |
| 9 | Rubber-tired horse vehicle | 2 | 5 | | |
| 10 | Saddle horse | 6 | 4 | 1 | 1 |
| 11 | Motor cycle | 37 | 42 | 9 | 10 |
| 12 | Excessively heavy vehicle[3] | 4 | 4 | 1 | 1 |
| 13 | Motor runabout | 95 | 88 | 27 | 33 |
| 14 | Motor touring car | 436 | 493 | 141 | 160 |
| 15 | Loaded motor dray | 35 | 41 | 18 | 24 |
| 16 | Unloaded motor dray | 10 | 13 | 4 | 3 |

---

[1] Viscous, sticky fluid.

[2] Width of surfacing taken as 16 feet.

[3] Very heavy vehicles, such as carry ore, stone, timber, machinery, etc.

## WASHINGTON, D. C., 1915.

### BITUMINOUS CONCRETE.

These experiments, constructed on the wing drives at either end of the main building of the United States Department of Agriculture, were described in Department Bulletin No. 407. At the time of inspection the surfaces were in excellent condition. They had had no repairs and required none. The only noticeable difference between the two experiments was the darker appearance and slightly closer texture of the surface constructed according to the District of Columbia specifications.

## BUENA VISTA, FLA., 1915.

### RESIDUAL ASPHALTIC PETROLEUM-CORALLINE ROCK.

This experiment was intended to serve as a check on section 6 of the Biscayne Drive experiments begun at Miami in 1913. The original report of the Buena Vista experiment appeared in Bulletin 407, U. S. Department of Agriculture. The following report is based on an inspection made December 22, 1916.

The traffic on this road has been very light and at the time of the inspection there was no evidence of wear on any portion. The surface showed some evidence of deterioration, however, from other causes. The following points were noted particularly:

(1) Uneven bleeding, due either to lack of uniformity in the original distribution of the bituminous material or to segregation of the different-sized particles of the aggregate. As a consequence, the surface presented a mottled appearance, and where sand had been added to the "fat" spots a surface mat had been formed, but because of the nature of the bituminous material this mat had not become bonded down firmly as a part of the road, but was easily loosened and scattered.

(2) A trench had been excavated across the road to receive a pipe leading to a pump house on the side of the road. After the trench was backfilled the road surface was tamped back in place and treated with oil of the kind used in the original construction. The surface over the trench was about three-fourths of an inch high, but otherwise satisfactory.

(3) About 50 feet of the south shoulder, near the pump house, was low and the surface showed a greater tendency to ravel here than on other portions of the road.

## JUPITER, PALM BEACH COUNTY, FLA., 1915.

### OIL-ASPHALT-SAND.

The original report of this experiment appeared in Bulletin No. 407, U. S. Department of Agriculture. The following report is based on an inspection made December 21, 1916. At that time the road had received no maintenance since its original construction in April, 1915, but was in fair condition. The surface had the general appearance of a road over sandy loam, except that the ruts of from 1½ to 2 inches were shallower than is usual with road surfaces of loam. The ruts in the natural sand road adjacent to the experiment were from 5 to 7 inches deep. Since the inspection of December 10, 1915, which was mentioned in the original report of this experiment, the coat of loose material on the surface had decreased in thickness to a minimum of about one-fourth of an inch and a maximum of about 1 inch. The path worn by horses in the center of the road was hardly noticeable. Instead of following the center line of the road, travel had followed a curved path, and near the center of the section the track was extremely close to the north edge of the surfacing. This no doubt was responsible for failure of the surfacing in several spots along the north rut, though some of the weak spots could not be explained in this way. The following is a list of the spots where partial or total failure has occurred, and which need immediate attention:

18 feet from east end of experiment, hole in center of road.
24 to 30 feet from east end of experiment, north one-half of road.
39 feet from the east end of experiment, center.
45 feet from east end of experiment, north rut.
66 feet from the east end of experiment, north rut.
71 feet from the east end of experiment, center and north rut.
84 feet from the east end of experiment, center.
100 feet from the east end of experiment, center and north rut.

The county officials at the time of inspection were preparing to treat the surface with asphaltic oil which was used extensively in construction of coralline-rock roads at the time. It was expected that such a surface treatment would check the disintegration at the points noted above, as well as prevent other defects from developing.

## WEST PALM BEACH, FLA., 1915.

### BITUMINOUS SAND.

In continuation of experiments Nos. 1 to 7 a section of sand-asphalt or bituminous sand surfacing was built in January, 1915, as experiment No. 8. Its construction is described in Bulletin 407, U. S. Department of Agriculture. This section was inspected on December 11, 1916, and its condition was as follows:

*Experiment No. 8—Bituminous sand.*—The surface showed waves at quite regular intervals. The sheet was intact, tough and very slightly calk-marked and pitted. No failure was apparent at any point and no difference in behavior of surface appearance was noticeable in the various parts of the experiment.

## OCALA, FLA., 1915.

### OIL-LIMESTONE, SAND-ASPHALT.

The original report of these experiments was published in Bulletin No. 407. U. S. Department of Agriculture. The following report is based upon an inspection made December 16, 1916, when, judging from the general condition of the road surface and shoulders, it was apparent that the experimental sections had received no maintenance since their construction.

*Experiment No. 1—Limestone, residual asphaltic petroleum; penetration method.*—The surface of this experiment appeared somewhat rougher than a year before, as the defects in construction showed more prominently owing to continued wear. At the same time this experiment demonstrates that with suitable care in construction a very satisfactory road can be built by the penetration method, using the soft Ocala limestone. At the time of inspection the section showed some areas which had pitted, owing to the excessive wear on large exposed fragments of stone or to picking out of individual pieces. In a few other places there had been apparently faulty distribution, owing in some instances to the wearing course having been bonded too tightly before the bituminous material was applied. Traffic is concentrated on a 9-foot strip and the wear has been quite uniform in the wheel tracks. Outside of the traveled way there was little evidence of wear. A seal coat over the entire section probably would prove of material benefit to the surface.

*Experiment No. 2—Sand-oil asphalt.*—This experiment was in practically the same condition as when completed in the summer of 1915. At the time of inspection there were some slight waves or depressions which appeared to have deepened little since construction, but at a few of the joints in the work slight depressions had formed. In a few places at the sides of the road, where there is no traffic, very slight cracks were apparent, but no cracks were evident where traffic exerts its action. In some places the limestone shoulders had worn considerably and needed immediate attention. So far as could be observed, the varying character of the base had caused no differences in the appearance of the surface and, as a whole the sand-asphalt experiment was in excellent condition.

## LEMON CITY, FLA., 1914.

### OILS, TAR PREPARATION, CALCIUM CHLORIDE-CORALLINE ROCK.

The original report of these experiments appeared in Bulletin No. 257, U. S. Department of Agriculture, and a subsequent report of an inspection in Bulletin No. 407, U. S. Department of Agriculture. The following report is based on an inspection made December 22, 1916:

In September, 1916, a treatment of crude oil was applied to the surface by the county road authorities. At the time of the inspection the surface was in good condition, except for one spot 115 feet from the north end of the sections. This spot is about 4 feet wide and 3 feet long and shows excess bituminous material and sand varying in thickness from three-quarters inch to 1¼ inches. The depressions noted in Bulletins Nos. 257 and 407 were not noticeable.

### WEST PALM BEACH, FLA., 1914.

#### OIL, TAR, AND OIL-ASPHALT WITH CORALLINE ROCK.

These experimental sections were constructed about 2 miles south of West Palm Beach in May, 1914. The original report giving details of materials, methods and traffic, is published in Bulletin No. 257, U. S. Department of Agriculture, and supplementary report of conditions in Bulletin No. 407, U. S. Department of Agriculture.

The work was inspected on December 11, 1916, and the condition of the sections at that time was as follows:

*Experiment No. 1—Residual asphaltic petroleum, 2.3 gallons, penetration method.*—This section continued in very satisfactory condition. More of the seal coat appeared to be left on the first section, station 0+00 to station 0+50, than on the second section of the experiment. A small hole left open at approximately station 0+25 is now an irregular opening about 4½ by 4½ inches and the edges show no tendency to travel. Where the seal coat is gone, the stone showed a mosaic surface with the exposed aggregate worn flat. A wooden block, unintentionally left in the surface near the right side at approximate station 0+75, and another near the left side at approximate station 0+85, gave indication of very little wear. Seven small pits in the surface were counted near the north end of the experiment. Both sections of the experiment would take a seal coat of about one-tenth gallon per square yard to advantage.

*Experiment No. 2—Refined coal tars, 1.3 gallons, penetration method.*—A hard, rather than leathery, seal coat was intact on about 60 per cent of this experiment, but where breaks occurred there was a marked tendency to pit. A block left in the surface at approximate station 1+79, 2½ feet from the right-hand side, gave indication of very little wear.

*Experiment No. 3—Refined coal tars, 1.2 gallons, penetration method.*—This experiment presented a mosaic appearance and showed a pitted area approximately three times that noted at the inspection one year before. Apparently the tendency to pit was greater in areas where excessively large aggregate occurred and possibly also over pockets of very fine aggregate or dust. This latter might have been produced by the breaking up of large aggregate by traffic and not indicate fine material in the original construction. From approximate station 2+44 to the end of the experiment, a crude-oil seal coat was applied and the pitting somewhat reduced. At approximate station 3+40 a mark across the experiment, which appeared to be a heavy lapping was very noticeable and considerable pitting occurred on both sides of it.

*Experiment No. 4—Residual asphaltic petroleum, 1.4 gallons, penetration method.*—A noticeable line at approximate station 4+15 distinguishes the two parts of the first section of this experiment. The first part showed little tendency to pit where the mat was entirely gone and the sand mortar tended to wear away from around the stone. The mat was approximately 60 per cent intact on this section. On the second part of this section the mat was three-fourths gone and the aggregate exposed had a mosaic appearance. The sand mortar generally wore from around the stone. Section 2 of this experiment had a mat of a dead drab appearance more generally intact than that of section 1. The section showed a slight tendency to pit.

*Experiment No. 5—Oil asphalt, 1.8 gallons, penetration method.*—This section continued to show little change in appearance, except that the wear on the mat was marked by lateral streaks, which may indicate application lines. There was some tendency to pit where the mat was gone entirely. A plug hole at approximate station 6+14, about 4 feet from the right side, showed a very little tendency to ravel.

*Experiment No. 6—Oil asphalt, 1.5 gallons, penetration method.*—This experiment was in practically perfect condition, except for normal wear.

*Experiment No. 7—Coralline rock, water-bound macadam.*—This experiment showed considerable wear, approximating one-fourth inch in depth generally over the whole surface and 2 inches or more over most of the cross section for a distance of several feet from its junction with experiment No. 6.

## MIAMI, FLA., 1913.

### OIL-CORALLINE ROCK.

The original report of these experiments appeared in Bulletin No. 105, U. S. Department of Agriculture, and subsequent reports of several inspections in Bulletin Nos. 257 and 407. The following report is based on inspections made on April 24 and December 22, 1916. During April a sewer trench was cut through the experimental sections. An examination of the surfaces at that time showed section No. 3 to be in fairly good condition. Sections 4 and 5 were failing and in a very poor condition. The bituminous material showed a penetration of from three-fourths to 1 inch. Section 6 was in excellent condition and showed no signs of local failures or undue wear at any point. The bituminous material showed a penetration of from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches.

In December Biscayne Drive and all the experimental sections received a top-dressing of light crude oil and coarse beach sand for the purpose of keeping down the dust during the tourist season. On December 22, when the road was last inspected, section 3 could hardly be distinguished from the surface-treated road adjacent, but it was evident that no serious break had occurred. Sections 4 and 5 were distinguishable by the numerous particles showing on the surface. Section 6 was in perfect condition, with the exception of the new surface over the sewer.

### RÉSUMÉ OF PREVIOUS REPORTS.

These experiments are located on the Biscayne Drive about 2 miles north of Miami, Fla. The road connects Miami with Fort Lauderdale, Palm Beach, and other cities along the east coast, and is subjected to a fairly heavy mixed traffic. The purpose of these experiments was to obtain a satisfactory and permanent surface from the use in construction of a selected bituminous binder with the native coralline rock. Table 50 indicates the method of construction of the experimental sections and shows their condition at the time of several inspections since construction. The tabulation shown has been prepared from reports of inspections made by this office, published in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture.

TABLE 50.—*Experiments at Miami, Fla.*

| Section No. | Length. | Description of the original construction in 1913 (Bulletin No. 105, U. S. Department of Agriculture). | Condition Dec., 1913 (Bulletin No. 105, U. S. Department of Agriculture). | Condition Jan., 1915 (Bulletin No. 257, U. S. Department of Agriculture). | Condition Dec., 1915 (Bulletin No. 407, U. S. Department of Agriculture). |
|---|---|---|---|---|---|
| | *Feet.* | | | | |
| 1 | 96 | *Semi-penetration method—cold, light oil.*—Old surface scarified, regraded, and left loose to a depth of 2 inches; cold, light oil applied at the rate of 0.9 gallon per square yard and allowed to soak in 2 hours before sanding and rolling; later rolling caused the surface to wave and crack; experiment gave small promise of success. | Very bad condition; section showed impracticability of employing penetration method on old coralline rock surface. | Worn out; will not be reported on again. | |
| 2 | 453 | *Surface treatment—cold, light oil.*—Old surface scarified, regraded, and waterbound; surface swept clean and cold, light oil applied at the rate of 0.5 gallon per square yard; after vigorous brooming the surface was sanded and rolled; construction hindered by rain. | Very poor condition.......... | Worn out; will not be reported on again. | |
| 3 | 200 | *Penetration method—hot, heavy oil.*—Old surface regraded and a course of new unscreened stone spread to a depth of 2½ inches loose, this rolled very lightly; light rains during rolling caused surface to become slightly waterbound; hot oil applied at the rate of 0.6 gallon per square yard; surface sanded and rolled as in section 2. | Very satisfactory condition.... | In fairly good condition, although it has worn somewhat rough; no breaks have occurred. | Practically in same condition as reported in inspection of Jan., 1915. |
| 4 | 167 | *Penetration method—cold, light oil.*—Similar to experiment No. 3, except that the stone course was heavily rolled; oil was applied at the rate of 0.7 gallon per square yard and allowed to stand 3 hours before sanding; practically all the oil was absorbed. | Practically the same as No. 3.. | In fair condition; not as satisfactory as section 3; a group of worn places noted just north the middle of the section; some repairs made. | This section was deteriorating rapidly; binder had become brittle and rock was becoming loose over the whole surface. |
| 5 | 239 | *Penetration method—hot, heavy oil.*—Same as section 4, except that the stone course was reduced to a loose thickness of 1½ inches; from station 9+16 to station 10+87 sand was used for a top dressing and from 10+87 to 11+55 rock screenings were used. | Surface not as satisfactory as Nos. 3 and 4, although only three small holes have developed up to this time. | Very poor; apparently no economy in reducing depth of stone course; 17 worn depressions ranging from one-half to 2 square feet in area distributed throughout the section; had been patched with coralline rock. | Worn depression and holes last reported had increased greatly in size and number; bituminous material had lost its cohesive power and was crumbling rapidly. |
| 6 | 107 | *Penetration method—hot, heavy oil.*—Stone passed over a ⅜-inch screen and the portion retained was spread to a loose depth of 3 inches on the graded road; oil was applied at the rate of 1 gallon per square yard, which was enough to flush the voids; from station 11+55 to station 11+80 stone screenings were used as a top dressing; over the remainder sand was used. | In excellent condition; adjacent untreated road worn about 1 inch below surface elevation of this section. | In excellent condition; cross section well preserved and gave small evidence of wear. | This section was still in excellent condition and had required no repairs whatever. |

## ROCKVILLE PIKE, MONTGOMERY COUNTY, MD., 1913.

### SURFACE TREATMENTS ON WATER-BOUND MACADAM.

The original report of these experiments was given in Bulletin No. 105, U. S. Department of Agriculture, and reports of inspections appear in Bulletins Nos. 257 and 407. The following report describes the condition of experiments on February 21, 1917.

*Experiment No. 1—Refined coal tar, hot application.*—This experiment continued to give trouble. Although the entire section was retreated in July, 1915, it became necessary to re-treat that part of the section, which was added in July, 1915, as described in Bulletin No. 407. Disintegration of the surface on this northern portion of the experiment had become so rapid that ordinary repairs were not adequate, and on October 18 to 21, 1916, the same bituminous material was used as in the original treatment of Experiment No. 1, an application of 0.33 gallon per square yard being made. On account of the lateness of the season and the possibility of low temperature, it was decided to broom the material in order to assure thorough contact with the old surface. The tar was delivered directly from the stills in tank wagons equipped with fire boxes and the material was distributed by gravity through a flat nozzle and thoroughly broomed. The material was applied uniformly and carefully in an effort to get the best possible results. The characteristics of a typical sample of the bituminous material are given in Table 51 and the cost data and quantities will be found in Table 53.

At the time of the inspection the entire experiment was in bad condition. South of Bradley Lane (the original experiment No. 1) the road was badly worn and had areas with large numbers of cup holes.

Considering the traffic on this section, the road is too narrow and the edges suffered severely on account of the frequent turning out of vehicles. North of Bradley Lane, which was re-treated as above described, the conditions were but little better. The road showed the same weaknesses and was requiring more bituminous patching than could be done in the season. It appeared probable that the entire section would require very heavy repairs and a general re-treatment as early in the spring as possible.

*Experiment No. 2—Refined water-gas tar, cold application.*—As contemplated in the last report, it became necessary to re-treat this section in July, 1916. Characteristics of a typical sample of the bituminous material used are given in Table 51, and the cost data and quantities in Table 53. The general condition of this experiment at the time of inspection was excellent, and generally the mat was hard, unbroken, and uniform.

TABLE 51.—*Analysis of refined tars used in re-treatment of experiments Nos. 1 and 2, Rockville Pike.*

| | Experiment No. 1. | | Experiment No. 2. | |
|---|---|---|---|---|
| Bituminous material | Coal tar refined | | Water-gas tar refined. | |
| Characteristics | Viscous, sticky | | Viscous, sticky. | |
| Specific gravity 25°/25° C | 1.209 | | 1.140. | |
| Float test 32° C., seconds | 135 | | | |
| Specific viscosity, Engler 50 c. c., 50° C | | | 19.4. | |
| Per cent free carbon | 13.56 | | 2.91. | |
| | Per cent by volume. | Per cent by weight. | Per cent by volume. | Per cent by weight. |
| Distillation: | | | | |
| First light oils (to 110° C.) | | | [3]0.20 | 0.14 |
| Second light oils (110° to 170° C.) | | | [3].10 | .08 |
| Heavy oils (170° to 270° C.) | [1]13.4 | 11.0 | [2]22.08 | 19.81 |
| Heavy oils (270° to 300° C.) | [2]7.8 | 6.5 | 12.04 | 10.82 |
| Pitch residue | 78.8 | 82.5 | 65.58 | 68.82 |
| Total | 100.0 | 100.0 | 100.0 | 99.67 |

[1] Solid. [2] Clear. [3] Cloudy.

*Experiment No. 3—Asphaltic petroleum, cold application.*—The action of this experiment is so well known that little description is necessary. Its conduct during the winters of 1915 and 1916 was thoroughly characteristic, and in June, 1916, it became necessary to re-treat as usual. The work was done by hand, as described in the last report, using the same bituminous material originally applied with torpedo sand as top-dressing. Table 52 shows the characteristics of the bituminous material and cost data will be found in Table 53.

All bottoms and all but the better drained slopes were thoroughly wet; one or two breaks had occurred near the top of the hill 600 feet from the south end of the experiment. The necessity for patching and re-treating during the following summer was evident.

TABLE 52.—*Analysis of asphaltic petroleums used in re-treatment of experiments Nos. 3 and 7, Rockville Pike.*

| | Experiment No. 3. | Experiment No. 7. |
|---|---|---|
| Specific gravity 25°/25° C | 0.945 | 0.952 |
| Flash point (° C.) | 37 | 18 |
| Burning point (° C.) | 93 | 30 |
| Specific viscosity, Engler, 50 c. c., 25° C | 97.5 | 90.9 |
| Loss at 163° C., 5 hours, 20 grams, per cent | 26.09 | 24.42 |
| Float test on residue, 50° C., seconds | 101 | 118 |
| Per cent of total bitumen insoluble in 86° B. naphtha | 14.67 | 10.47 |
| Per cent fixed carbon | 8.5 | 4.50 |
| Bitumen soluble in $CS_2$ (total bitumen), per cent | 99.85 | 99.92 |
| Organic matter insoluble | .15 | .05 |
| Inorganic matter insoluble | .00 | .03 |
| Total | 100.00 | 100.00 |

*Experiment No. 4—Residual asphaltic petroleum, hot application.*—Although section 4 had been patched heavily for over a year, it was decided in the summer to attempt to carry it through one more winter without general re-treatment. It was somewhat doubtful whether this was the best policy, for the section was acting very much as section 7 did during its second winter when re-treatment was postponed. There were a great number of breaks, small but prevailing generally over most of the section, showing more or less uniform failure of the mat. At some points a slight rutting had begun and made probable the necessity for very heavy patching and re-treatment early in the season.

*Experiment No. 5—Residual asphaltic petroleum, hot application.*—The condition of this experiment was comparable with that of experiment No. 4, although the disintegration did not appear to be quite so uniform. Though the surface was wet in all bottoms and poorly drained sections, there were larger areas almost intact. On the wet sections, the mat showed a tendency to break and form mud and considerable patching and it was thought a general re-treatment would be necessary the following summer.

TABLE 53.—*Materials and cost data for surface re-treatment, Rockville Pike, in 1916.*

| Item. | Experiment No. 1, refined coal tar (hot). | Experiment No. 2, refined water-gas tar (cold). | Experiment No. 3, asphaltic petroleum (cold). | Experiment No. 7, asphaltic petroleum (cold). |
|---|---|---|---|---|
| Area treated..........square yards.. | 4,825 | 7,475 | 12,333 | 11,148 |
| Quantity of material per square yard: | | | | |
| Bituminous material..........gallons.. | 0.33+ | 0.157 | 0.154 | 0.16 |
| Gravel..........cubic yards.. | .011+ | .012+ | .......... | .......... |
| Sand..........do.... | .......... | .......... | .011 | .01 |
| Cost per square yard (cents): | | | | |
| Bituminous material.......... | 3.00 | 1.71 | 1.65 | 1.92 |
| Gravel.......... | 2.93 | 3.27 | .......... | .......... |
| Sand.......... | .......... | .......... | 2.86 | 2.76 |
| Cleaning surface.......... | .27 | .07 | .08 | .05 |
| Hauling materials.......... | .......... | .41 | .59 | .82 |
| Applying bituminous materials.......... | .16 | .29 | .31 | .22 |
| Applying sand or gravel.......... | .22 | .26 | .22 | .30 |
| Supervision.......... | .22 | .32 | .24 | .24 |
| Total.......... | 6.80 | 6.33 | 5.95 | 6.31 |

TABLE 54.—*Surface maintenance cost of experiments on Rockville Pike to December 31, 1916.*

| Experiment No. | Length. | Area. | Total cost per sq. yd. prior to Dec. 31, 1915. | Surface maintenance per sq. yd. during 1916. | Total cost of surface per sq. yd. to Dec. 31, 1916. | Surface maintenance per mile for year 1916. |
|---|---|---|---|---|---|---|
| | *Feet.* | *Sq. yds.* | *Cents.* | *Cents.* | *Cents.* | |
| 1.......... | 9,060 | 15,100 | 27.70 | 5.26 | 32.96 | $462.88 |
| 2.......... | 4,425 | 7,375 | 18.89 | 6.83 | 25.72 | 601.04 |
| 3.......... | 7,400 | 12,333 | 20.42 | 6.87 | 27.29 | 604.56 |
| 4.......... | 7,100 | 11,833 | 15.21 | 2.41 | 17.62 | 211.20 |
| 5.......... | 6,775 | 11,292 | 15.32 | 2.21 | 17.53 | 194.48 |
| 6.......... | 6,325 | 10,542 | 27.53 | 1.34 | 28.87 | 117.92 |
| 7.......... | 6,689 | 11,148 | 20.41 | 6.87 | 27.28 | 604.56 |

*Experiment No. 6—Water-gas tar preparation, hot application.*—The re-treatment of this section in November, 1915, put the surface in first-class condition and at the time of inspection it showed little wear, no breaks, and only a few small areas where moisture had permeated the mat. In general, the surface remained in fine condition.

*Experiment No. 7—Asphaltic petroleum, cold application.*—As contemplated in the last report, this experiment required re-treatment early in July, 1916. The characteristics of the bituminous material used are given in Table 52 and the quantities and cost data are given in Table 53. At the time of inspection the surface was in good condition for the season. It had not become so muddy as usual and the mat was much more uniform. Traffic census had been continued, regular counts having been taken for a 24-hour period every thirteenth day. A tabulation of the maximum and average of each class of traffic for the calendar year 1916 is given in Table 55. Traffic south of the census station is on experiment No. 1 only; that north of the station is on experiments Nos. 2 to 7, inclusive. Maintenance by patrolmen was continued during the year and Table 54 shows comparative cost data to December 31, 1916, for the various experiments included in this project.

TABLE 55.—*Volume and character of traffic on Rockville Pike.*

| | | Section 1. | | | | Sections 2 to 7. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum. | | Average. | | Maximum. | | Average. | |
| | | North bound. | South bound. | North bound. | South bound. | North bound. | South bound. | North bound. | South bound. |
| 1 | Loaded 1-horse wagon | 30 | 18 | 18 | 9 | 22 | 11 | 10 | 5 |
| 2 | Unloaded 1-horse wagon | 17 | 31 | 7 | 14 | 8 | 17 | 4 | 7 |
| 3 | Loaded 2-horse wagon | 46 | 20 | 28 | 14 | 29 | 14 | 6 | 3 |
| 4 | Unloaded 2-horse wagon | 15 | 41 | 4 | 13 | 6 | 28 | 2 | 4 |
| 5 | Loaded 4-horse wagon | 5 | 6 | 1 | 1 | 5 | 5 | ........ | 1 |
| 6 | Unloaded 4-horse wagon | 4 | 3 | 1 | ........ | 4 | 1 | ........ | ........ |
| 7 | 1-horse pleasure vehicle | 22 | 21 | 12 | 11 | 11 | 14 | 5 | 5 |
| 8 | 2-horse pleasure vehicle | 2 | 1 | ........ | ........ | 1 | 1 | ........ | ........ |
| 9 | Rubber-tired horse vehicle | 2 | 2 | ........ | ........ | 1 | 1 | ........ | ........ |
| 10 | Saddle horse | 11 | 21 | 5 | 6 | 7 | 16 | 2 | 3 |
| 11 | Motor cycle | 74 | 71 | 17 | 19 | 57 | 61 | 15 | 15 |
| 12 | Excessively heavy vehicle[1] | 23 | 7 | 2 | 1 | 3 | 3 | ........ | ........ |
| 13 | Motor runabout | 105 | 110 | 50 | 50 | 82 | 87 | 34 | 33 |
| 14 | Motor touring car | 694 | 793 | 209 | 216 | 611 | 700 | 158 | 164 |
| 15 | Loaded motor dray | 66 | 55 | 40 | 32 | 41 | 46 | 23 | 23 |
| 16 | Unloaded motor dray | 16 | 42 | 5 | 13 | 12 | 12 | 3 | 5 |

[1] Very heavy vehicles, such as carry ore, stone, timber, machinery, etc.

## WASHINGTON, D. C., 1912.

### TAR PREPARATION AND OILS, SURFACE TREATMENT.

The original report of these experiments was published in Circular No. 99 of the Office of Public Roads, and inspection reports have appeared in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture. The following report describes the maintenance during the year 1916 and the condition of the experiments March 28, 1917.

*Section No. 1—Refined water-gas-tar preparation.*—Although it seemed, in February, 1916, that this experiment probably would not require a re-treatment in the summer, wear developed uniformly until the mat became so thin that it was thought best to re-treat. This was done by hand in October, and the quantities and costs appear in Table 58. The same type of bituminous material was used as in the original surface treatment and the covering was torpedo sand. Analysis of a sample of the bituminous material is shown in Table 56. At the time of last inspection, March 28, 1917, this experiment had a mat generally intact and uniformly worn. Near the north end there were a few small breaks in the surface near the center of the roadway.

TABLE 56.—*Analysis of water-gas tar preparation*[1] *used in re-treatment of experiment No. 1, Washington, D. C.*

| | | |
|---|---|---|
| Specific gravity 25°/25° C. | | 1.117 |
| Specific viscosity, Engler, 50° C., 50 c. c. | | 18.5 |
| Per cent free carbon | | 2.05 |
| Distillation: | Per cent by volume. | Per cent by weight. |
| Water | 0.0 | 0.0 |
| First light oils (to 110° C.) | 1.0 | .7 |
| Second light oils (110° to 170° C.) | .5 | .3 |
| Heavy oils (170° to 270° C.) | 21.0 | 19.1 |
| Heavy oils (270° to 300° C.) | [2] 10.0 | 9.6 |
| Pitch residue | 67.5 | 70.3 |
| Total | 100.0 | 100.0 |

During the autumn and winter of 1916 this experiment was subjected to a much heavier steel traffic than ever before, owing to construction operations on the department grounds. About 100 feet from the south end of the section a wide trench was cut through the roadway and was filled with cinders. A second trench, about 15 inches wide, had been cut through at a point 275 feet from the south end, and when filled the surface treatment had been patched. At the time of inspection the fill had settled somewhat and probably will have to be repaired. Other than the repairs over these trenches, the surface needed slight repairs and a light re-treatment during the summer.

*Section No. 2—Asphaltic petroleum, surface treatment.*—As contemplated at the time of last inspection report, this experiment required considerable patching and a re-treatment during the summer of 1916. The quantities and costs appear in Table 58, and the characteristics of the bituminous material used are given in Table 57. This was the same as used in the original treatment.

---

[1] Fairly viscous fluids.

[2] The 270° to 300° C. portion showed 5 per cent insoluble in dimethyl sulphate.

When inspected on March 27, 1917, this surface showed a larger degree of failure than ever before. The first 175 feet from the west end has a line of "cup" holes, generally confined to the middle third of the roadway. The mat was smooth and almost perfect over the next 100 feet, and there were only two small breaks. Then followed another section about 40 feet long spotted with the characteristic "cup" holes. The mat close to the "cup" holes was unbroken and although many of the holes were not over 3 or 4 inches in diameter and probably 90 per cent not over 8 inches across, many were an inch deep and some as much as 1½ inches. Along the last 200 feet at the east end of the section, seepage from the bank had done more damage than in any previous year. The "cup" holes continued along this part of the road, with an almost intact mat between them. This experiment showed the need of considerable repair and a general re-treatment in the summer.

*Sections 3 and 4—Asphaltic petroleum.*—Section 3 was repaired thoroughly in the summer of 1916 and given a re-treatment at the same time as section 4, and the same materials were used, so that the two sections are alike. Owing to the variation in past history, however, the three sections, 2, 3, and 4, will be continued separately so far as necessary. The re-treatment costs for section 3 appear in Table 58 and the analysis of the bituminous material is given in Table 57.

TABLE 57.—*Analysis of asphaltic petroleums used in re-treatment of experiments Nos. 2, 3, and 4, Washington, D. C.*

| | Experiment No. 1. | Experiments Nos. 3 and 4. |
|---|---|---|
| Specific gravity 25°/25° C. | 0.950 | 0.956 |
| Flash point (° C.) | 18 | 28 |
| Burning point (° C.) | 27 | 50 |
| Specific viscosity, Engler 25° C., 50 c. c. | 108.6 | 187.5 |
| Loss at 163° C., 5 hours, 20 grams ... per cent. | 22.45 | 28.23 |
| Float test on residue, 50° C. seconds | 119 | 188 |
| Per cent of total bitumen insoluble in 86° B. naphtha | 8.08 | 16.58 |
| Fixed carbon ... per cent. | 5.49 | 9.04 |
| Bitumen soluble in $CS_2$ (total bitumen) ... per cent. | 99.95 | 99.95 |
| Organic matter insoluble ... per cent. | .05 | .05 |
| Inorganic matter insoluble ... per cent. | .00 | .00 |
| Total ... per cent. | 100.00 | 100.00 |

The mat on section 3 in March, 1917, was failing quite generally over all but 150 feet, where the drainage was best. Raveling of the macadam had started in a number of places and the effects of poor drainage, especially for the westerly 250 feet where the roadway is in cut, was more evident than at any time since construction. The south side had softened and rutted and many of the broken areas in the surface had spread until they had run together and a general disintegration of the surface appeared imminent. It appeared probable that reconstruction of the macadam would be necessary.

Section 4 was re-treated in October, 1916, and at the time of inspection was in almost perfect condition. A few small spots near the north end showed excessive wear, but otherwise the surface was uniform and intact. The quantities and costs appear in Table 58, and the characteristics of the bitumen, which was the same as used in original construction, were the same as of that used on section 3.

TABLE 58.—*Materials and cost data for surface re-treatment, Washington, D. C., in 1916.*

| Item. | Experiment No. 1, refined water-gas tar preparation. | Experiment No. 2, asphaltic petroleum. | Experiment Nos. 3 and 4, asphaltic petroleum. |
|---|---|---|---|
| Area treated……sq. yds.. | 1,318 | 1,129 | 2,041 |
| Quantity of material per square yard: | | | |
| Bituminous material……galls.. | 0.138 | 0.152 | 0.113 |
| Sand……cu. yds.. | .0064 | .0053 | .0046 |
| Cost per square yard (cents): | | | |
| Bituminous material | 1.38 | 1.70 | 1.81 |
| Sand | 1.03 | .86 | .73 |
| Cleaning surface | .05 | .06 | .13 |
| Hauling materials | 1.08 | .27 | .88 |
| Applying bituminous materials | .42 | .56 | .56 |
| Applying sand | .41 | .49 | .17 |
| Supervision | .41 | .48 | .36 |
| Total | 4.78 | 4.42 | 4.64 |

## CHEVY CHASE, MD., 1912.

### BITUMINOUS CONCRETE, CEMENT CONCRETE, OIL CEMENT CONCRETE, VITRIFIED BRICK, BITUMINOUS SURFACE TREATMENTS ON CONCRETE.

The original reports of these experiments were begun in Circular No. 99 of the Office of Public Roads and completed in Bulletin No. 105, U. S. Department of Agriculture, and supplementary reports have been published in Bulletins Nos. 257 and 407, U. S. Department of Agriculture. The following report covers the condition of experiments on February 21, 1917.

*Experiment No. 1—Bituminous concrete, Topeka specification.*—This section continued in essentially the same condition as at last report. At points 15, 25, and 30 feet from the north end of the limestone section three cracks appeared, extending about one-half of the width of the surface on the gutter side. About 70 feet from the north end of the trap section, near the gutter, there were two breaks with an area of about 1 square foot each. In one of these the concrete base was exposed. The slight pitting noted in the last report had not increased.

*Experiment No. 2—Bituminous concrete, District of Columbia specification.*—This surface continued in the same condition as when last reported. Two cracks have appeared at 50 and 65 feet, respectively, from the north end on the track side and extend about two-thirds across the width of the surface. Slight pitting, due to the disintegration of exposed rock particles, was still noticeable, but there was no increase over that reported last year. The repairs made at the expansion joint, described in the last report, appear to have been adequate, as no further trouble has been experienced at this point.

*Experiment No. 3—Cement concrete and oil cement concrete; surfaces treated with bituminous materials.*—During the autumn the entire surface of experiment No. 3 received a carpet treatment with torpedo sand as a top-dressing. Sections A, B, G, and H were treated with a water-gas tar preparation, and sections C, D, E, and F with a residual asphaltic petroleum. Sections I and J received a carpet coat in two applications of one-half gallon of cold asphaltic petroleum. The first application was top-dressed with torpedo sand and allowed to stand 48 hours, after which the second application was made and additional top dressing applied. The material and cost data for these treatments are given in Table 59.

TABLE 59.—*Materials and cost data for surface retreatment in 1916, Experiment No. 3.*

| Item. | Sections C, D, E, and F, residual asphaltic petroleum. | Sections A, B, G, and H, water-gas tar preparation. | Sections I and J, asphaltic petroleum. |
|---|---|---|---|
| Area treated ... sq. yds. | 1,725 | 1,840 | 667 |
| Quantity of material per square yard: | | | |
| Bituminous material ... galls. | 0.275 | 0.306 | 0.499 |
| Sand ... cu. yds. | .0078 | .0084 | .0149 |
| Cost per square yard (cents): | | | |
| Bituminous material | 3.00 | 4.14 | 5.94 |
| Sand | 1.64 | 1.77 | 3.18 |
| Cleaning surface | .30 | .12 | .44 |
| Applying bituminous materials | .89 | .87 | .85 |
| Applying sand | .27 | .25 | .44 |
| Supervision | .23 | .66 | .80 |
| Total | 6.33 | 7.81 | 11.65 |

*Sections A and B:* These sections were in almost perfect condition except for a distance of about 30 feet at the south end, which was treated in cold weather. Over this portion of the experiment there were quite a number of small scars, where the treatment had been removed by traffic.

*Sections C, D, E, and F:* This mat was noticeably heavier than that resulting from the application of water-gas tar and had a distinctly leathery texture. About 10 feet south of the E post there was one small break, the only one on the section. Slight calk marks were visible and quite generally distributed, and there appeared to be a tendency to push, but the wavy condition was barely noticeable.

*Sections G and H:* These sections showed no breaks, and the surface was smooth, but the wear near the center had exposed the concrete in a number of places.

TABLE 60.—*Analysis of water-gas tar preparation*[1] *used in surface treatment of concrete experiment.*

| | |
|---|---|
| Specific gravity 25°/25° C. | 1.155 |
| Float test 32° C. (seconds), 321; 50° C. (seconds) | 84 |
| Per cent free carbon | 2.22 |

| Distillation: | Per cent by volume. | Per cent by weight. |
|---|---|---|
| Water | 0.0 | 0.0 |
| First light oils (to 110° C.) | .0 | .0 |
| Second light oils (110° to 170° C.) | .0 | .0 |
| Heavy oils (170° to 270° C.) | [2] 14.1 | 11.7 |
| Heavy oils (270° to 300° C.) | [2] 8.9 | 7.4 |
| Pitch | [3] 77.0 | 80.9 |
| Total | 100.0 | 100.0 |

| Dimethyl sulphate test: Fraction: | Per cent by volume. | Per cent insoluble. |
|---|---|---|
| 270° to 300° C. | 8.9 | 0.0 |
| 300° to 350° C. | 20.8 | 5.0 |
| 350° to 375° C. | 7.0 | 17.5 |

TABLE 61.—*Analysis of petroleum products used in surface treatment of concrete experiment.*

| | Sections C, D, E, and F, residual asphaltic petroleum. | Sections I and J, asphaltic petroleum. |
|---|---|---|
| Specific gravity 25°/25° C. | 0.993 | 0.945 |
| Flash point, °C. | | 37 |
| Burning point °C. | | 93 |
| Specific viscosity, Engler, 50 c. c. | [1] 13.5 | [2] 97.5 |
| Float test at 50° C., seconds | 28 | |
| Loss at 163° C., 5 hours, 20 grams, per cent | 13.71 | 26.09 |
| Float test on residue 50° C., seconds | 151 | 101 |
| Per cent of total bitumen insoluble in 86° B. naphtha | 18.63 | 14.67 |
| Fixed carbon, per cent | 11.25 | 8.5 |
| Bitumen soluble in $CS_2$ (total bitumen), per cent | 99.89 | 99.85 |
| Organic matter insoluble, per cent | .08 | .15 |
| Inorganic matter insoluble, per cent | .03 | .00 |
| Total per cent | 100.00 | 100.00 |

[1] At 100° C. [2] At 25° C.

*Sections I and J:* These sections were much like C to F and had a rubbery mat with few breaks, but a tendency to push. With cold and moisture the mat became somewhat mealy under traffic.

*Experiments Nos. 4 and 5—Oil cement concrete; cement concrete.*—There was less distinction apparent this year between experiments Nos. 4 and 5. The gravel aggregate showed a very material wear in No. 5. The limestone appeared to be worn more than the gravel, as evidenced by conditions along the eastern 4 feet of the surface and especially over the last 50 feet of experiment No. 4, south of the Columbia Club main entrance.

*Experiment No. 6—Vitrified brick.*—There has been no great difference in apparent wear between the several sections of this experiment.

---

[1] Very viscous. [2] Clear. [3] Hard, brittle.

Local failures occurred in sections K and L amounting in all to about 200 square feet. A profile has been run along both sides and along the center of the experiments indicating that there has been considerable settlement in the sections where local failures occurred. It was expected that repairs would be made in the spring by cutting out the depressed areas, keying the edges carefully and patching with brick similar to that used in the original work.

A traffic census has been taken on this road every 13 days for a 24-hour period. A tabulation of the maximum and average for each class of traffic for the calendar year 1916 is given in Table 62. The west side of the road carries south-bound traffic coming from the railroad and the east side carried north-bound traffic toward the railroad.

The total cost of each experiment to December 31, 1916, are shown in Tables 59 and 63.

TABLE 62.—*Volume and character of traffic on Kensington Road north and south of Bradley Lane, January 1 to December 30, 1916.*

| | | North. | | | | South. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum. | | Average. | | Maximum. | | Average. | |
| | | North bound. | South bound. | North bound. | South bound. | North bound. | South bound. | North bound. | South bound. |
| 1 | Loaded 1-horse wagon | 7 | 30 | 3 | 14 | 18 | 17 | 10 | 8 |
| 2 | Unloaded 1-horse wagon | 9 | 20 | 3 | 9 | 9 | 16 | 5 | 7 |
| 3 | Loaded 2-horse wagon | 18 | 60 | 4 | 24 | 17 | 58 | 7 | 23 |
| 4 | Unloaded 2-horse wagon | 24 | 30 | 8 | 13 | 49 | 15 | 21 | 4 |
| 5 | Loaded 4-horse wagon | 1 | 3 | ........ | ........ | 3 | 2 | ........ | ........ |
| 6 | Unloaded 4-horse wagon | 1 | 1 | ........ | ........ | 1 | 1 | ........ | ........ |
| 7 | One-horse pleasure vehicle | 7 | 21 | 2 | 6 | 12 | 10 | 6 | 5 |
| 8 | Two-horse pleasure vehicle | 1 | 6 | ........ | ........ | 4 | 1 | ........ | ........ |
| 9 | Rubber-tired horse vehicle | 5 | 3 | ........ | ........ | 5 | 3 | ........ | ........ |
| 10 | Saddle horse | 10 | 11 | 3 | 2 | 15 | 10 | 3 | 3 |
| 11 | Motor cycle | 8 | 32 | 2 | 12 | 50 | 39 | 13 | 12 |
| 12 | Excessively heavy vehicle[1] | 5 | 5 | ........ | 1 | 6 | 7 | 1 | 1 |
| 13 | Motor runabout | 38 | 127 | 12 | 54 | 206 | 143 | 78 | 56 |
| 14 | Motor touring car | 295 | 635 | 83 | 264 | 858 | 711 | 386 | 293 |
| 15 | Loaded motor dray | 32 | 82 | 7 | 51 | 71 | 59 | 43 | 35 |
| 16 | Unloaded motor dray | 13 | 40 | 2 | 12 | 30 | 24 | 7 | 12 |

[1] Very heavy vehicles, such as carry ore, stone, timber, machinery, etc.

TABLE 63.—*Surface maintenance costs of 1912 experiments at Chevy Chase, Md., to December 31, 1916.*

| Experiment No. | Area. | Maintenance cost of experiments. | | | Total cost per square yard. | | |
|---|---|---|---|---|---|---|---|
| | | Total for experiments to Dec. 31, 1915. | 1916. | Total. | Construction. | Maintenance. | Total. |
| | *Sq. yds.* | | | | *Cents.* | *Cents.* | *Cents.* |
| 1 | 1,498 | $3.25 | ........ | $3.25 | 186.62 | 0.22 | 186.84 |
| 2 | 1,400 | 7.66 | $3.61 | 11.27 | 195.65 | .80 | 196.45 |
| 3[1] | 4,178 | 3.57 | 338.76 | 342.33 | [2]154.95 | 8.19 | 163.14 |
| 4[1] | 1,744 | 20.50 | 17.66 | 38.16 | [2]150.25 | 2.19 | 152.44 |
| 5 | 3,013 | 22.73 | 8.28 | 31.01 | [2]142.29 | 1.03 | 143.32 |
| 6 | 2,055 | 1.77 | 1.59 | 3.36 | 258.21 | .16 | 258.37 |

[1] In the progress report for 1915 the square yardage of experiment No. 4 included all oil-cement concrete. In October, 1916, sections G, H, I, and J were surface treated with bituminous materials and torpedo sand, restoring them to their original condition, and reducing the area of the oil cement concrete experiment to 1,744 square yards, as originally constructed. The area of experiment No. 3, which is now entirely surface-treated, is correspondingly increased to 4,178 square yards.

[2] Weighted average price for different sections.

## CHEVY CHASE, MD., 1911.

### BITUMINOUS CONSTRUCTION AND SURFACE TREATMENT.

The original reports of these experiments are given in Circulars Nos. 98 and 99, Office of Public Roads, and supplementary reports appear in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture. The following report is based upon an inspection made February 21, 1917.

*Section No. 1—Refined coal tar, penetration method.*—Except at the narrow part of the section where traffic is much concentrated, this surface presented an excellent appearance. The wear has been even and a uniform, slightly mosaic condition prevails. At the curve the aggregate was exposed quite generally and a few shallow patches were needed. It appeared probable that a re-treatment of this portion with about 0.25 gallon per square yard would be required in the spring. The gutter on the west side of the section continued to give trouble and is responsible for a slight roughness at this place.

*Section No. 2—Refined coal tar, modified Gladwell method.*—The condition of this section continued satisfactory. The slight roughness along the gutter edge noted in the last inspection report had not increased, and except for a strip about 4 feet wide on the track side of the section, the surface was in practically perfect condition. The 4-foot strip required a little patching and would be benefited by a re-treatment.

*Section No. 3—Fluxed native asphalt, penetration method.*—The wear on this section, noted as being somewhat irregular last year, was much more even and the experiment is conspicuous on account of the uniform condition over the entire cross section. Only a few large stones were noticeable throughout the surface.

*Section No. 4—Gilsonite oil-asphalt, penetration method.*—The south end of this section did not require the heavy patching expected last season and continued in fair, but uneven, condition. The north end is heavily patched, especially along the track side. The mat continued in about the same condition as last year, but the surface was somewhat more uneven than that of section No. 3.

*Section No. 5—Oil asphalt, penetration method.*—The east and west parts of this experiment were much more nearly alike than in 1915. The east side has failed just as the west side did; heavy patching was needed. The west side continued intact as a result of the patching done, but both sides were rough and wavy.

*Section No. 6—Oil asphalt, penetration method.*—The east side of this experiment continued generally better than the west side. On the west side about 60 feet south of the Chevy Chase Club entrance there were two breaks through the surface, but the corrugations near the gutter had not increased and the surface otherwise was intact. It was much smoother than that of No. 5 throughout the traveled way.

*Section No. 7, A and B—Oil asphalt, penetration method.*—Section A continued distinctly more mosaic than B and required a little patching. Section B had the aggregate exposed in numerous spots along the east half and needed somewhat heavy patching in the spring, to go through the season. The west half toward the trolley tracks was much better and less moisture appeared through the surface than near the gutter.

*Section No. 8—Refined water-gas tar preparation, surface treatment.*—During the past summer experiment No. 8 was re-treated with the same type of bituminous material as used in previous treatments, and the section appeared to be better than is usual in winter. The recent treatment, however, wore away in small areas, exposing the smooth surface of earlier treatments beneath. There were no breaks in the surface, and the wear since the last re-treatment has been uniform with the surface, smooth and regular. This experiment indicated need of re-treatment in the summer. The cost of the re-treatment is given in table 65.

*Section No. 9—Asphaltic petroleum, surface treatment; Section No. 10—Residual petroleum, surface treatment.*—Section 9 was again re-treated during the past season. South of Kirke Street the east half of the section was wet and rough, but the rest of the section was better than is usual at the time of inspection, and presented a generally smooth surface, except for waviness on the east one-third. It seemed probable that the section would require another treatment. Table 64 gives an analysis of the bituminous materials used in re-treating sections Nos. 9 and 10, and the cost of re-treatments appear in Table 65.

Both ends of section No. 10 were rather better than usual at this season of the year but the middle one-third was bad, having developed the characteristic pot-holes at more or less regular intervals, owing apparently to the rhythmic impact of automobile traffic.

TABLE 64.—*Analysis of asphaltic petroleum used in retreatment of sections 9 and 10.*

| | |
|---|---|
| Specific gravity 25°/25° C | 0.952 |
| Flash point (° C.) | 18 |
| Burning point (° C.) | 30 |
| Specific viscosity, Engler 50 c. c., 25° C | 90.9 |
| Loss at 163° C., 5 hours, 20 grams, per cent | 24.42 |
| Float test on residue, 50° C., seconds | 118 |
| Per cent of total bitumen insoluble in 86° B. naphtha | 10.47 |
| Per cent fixed carbon | 4.50 |
| Bitumen soluble in $CS_2$ (total bitumen) | 99.92 |
| Organic matter insoluble | .05 |
| Inorganic matter insoluble | .03 |
| Total | 100.00 |

TABLE 65.—*Materials and cost data for surface re-treatment, Chevy Chase, Md., in 1916.*

| Item. | Experiment No. 8, refined water-gas tar preparation. | Experiment No. 9, asphaltic petroleum. | Experiment No. 10, asphaltic petroleum. |
|---|---|---|---|
| Area treated..........square yards.. | 1,477 | 761 | 1,013 |
| Quantity of material per square yard: | | | |
| Bituminous material..........gallons.. | 0.149 | 0.289 | 0.299 |
| Gravel..........cubic yards.. | .......... | .0138 | .0114 |
| Sand..........do..... | .0115 | .......... | .......... |
| Cost per square yard (cents): | | | |
| Bituminous material.......... | 1.85 | 3.47 | 3.59 |
| Gravel.......... | .......... | 3.53 | 2.91 |
| Sand.......... | 2.95 | .......... | .......... |
| Cleaning surface.......... | .13 | .03 | .30 |
| Hauling materials.......... | .41 | .54 | .49 |
| Applying bituminous materials.......... | .55 | .19 | .23 |
| Applying sand or gravel.......... | .25 | .26 | .36 |
| Supervision.......... | .41 | .74 | 1.02 |
| Total.......... | 6.55 | 8.76 | 8.90 |

TABLE 66.—*Surface maintenance costs of 1911 experiments at Chevy Chase, Md., to December 31, 1916.*

| Experiment No. | Area. | Maintenance cost of experiments. | | | Total cost per square yard. | | |
|---|---|---|---|---|---|---|---|
| | | Total for experiments to Dec. 31, 1915. | 1916 | Total. | Construction. | Maintenance. | Total. |
| | *Sq. yds.* | | | | *Cents.* | *Cents.* | *Cents.* |
| 1.......... | 1,581 | $128.45 | $4.23 | $132.68 | 46.18 | 8.39 | 54.57 |
| 2.......... | 705 | 16.14 | 4.55 | 20.69 | 64.42 | 2.93 | 67.35 |
| 3.......... | 1,555 | 14.71 | 5.92 | 20.63 | 64.69 | 1.33 | 66.02 |
| 4.......... | 1,555 | 46.77 | 10.32 | 57.09 | 57.18 | 3.67 | 60.85 |
| 5.......... | 1,447 | 305.50 | 7.75 | 313.25 | 58.27 | 21.65 | 79.92 |
| 6.......... | 1,555 | 35.62 | 8.85 | 44.47 | 68.22 | 2.86 | 71.08 |
| 7a.......... | 131 | 6.58 | 2.90 | 103.19 | 59.96 | 10.54 | 66.03 |
| 7b.......... | 848 | 93.71 | | | 54.80 | | |
| 8.......... | 1,477 | 130.80 | 117.05 | 247.85 | 39.59 | 16.78 | 56.38 |
| 9.......... | 761 | 148.22 | 77.97 | 226.19 | 42.01 | 29.72 | 71.73 |
| 10.......... | 1,013 | 437.84 | 131.16 | 569.00 | 44.31 | 56.17 | 100.48 |
| 11.......... | 377 | 0.00 | 5.88 | 5.88 | 81.51 | 1.56 | 83.07 |

*Section No 11—Native asphalt emulsion, macadam surfacing.*—This section never has been re-treated and it has required no patching until the past season, when a few slight breaks were repaired. The mat was breaking rapidly and at date of inspection there were numerous places where the aggregate was exposed and four or five places where raveling was imminent, with moisture coming through about 60 per cent of the surface. It was probable that considerable patching and a reseal would be required in the spring.

*Maintenance during 1916*—In addition to the general re-treatments, as above described, the patrol system of maintenance was continued during the year. Table 66 presents the total cost of all maintenance, including the re-treatments shown in Table 65

A traffic census was taken every 13 days for a 24-hour period. The maximum and average of each class of traffic for the calendar year 1916 is shown in Table 62. Each side of the road carried traffic in one direction only.

### JAMAICA, N. Y., 1911.

#### OIL-CEMENT CONCRETE, OIL-ASPHALT, TAR, AND FLUXED NATIVE ASPHALT.

The original report of these experiments was published in Circular No. 98, and reports of annual inspections and repairs are given in Circular 99, Office of Public Roads, and in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture. The following report relates to the condition of the pavement on January 23, 1917:

*Experiment No. 1—Oil-cement concrete.*—In September, 1916, the old bituminous surface was loosened and removed. The concrete pavement for about 20 feet on each end of this section was broken up and rolled down with a steam roller to about 2 inches below the abutting grade. The whole area of this section was then covered with a 2-inch surfacing of Topeka asphaltic concrete.

*Experiment No. 2—Cut-back oil-asphalt, mixing method.*—The easterly 50 feet has been patched considerably and is in bad condition.

*Experiment No. 3—Fluxed native asphalt, mixing method.*—This section was in good condition except at places where cuts had been made for house connections and along the sides where the foundation had been poor. The waves in the surface on the north side at the east end had become 2 to 3 inches in depth and were lengthening westerly. They seemed to have originated from the waves in the adjoining section. The seal coat was wearing thin throughout the section.

*Experiment No. 4—Refined coal tar, mixing method.*—The tar seal coat on the westerly half was worn nearly off. The whole surface showed waviness, especially along the north edge for a width of 5 feet from station 8 to station 9 and for a width of 10 feet on the south side from station 8+45 to station 9+50 where the surface has disintegrated in places to a depth of from 1 to 3 inches. The asphalt seal coat on the easterly half was becoming thin and worn through in several places. Several shallow potholes had formed along the north side from station 9+50 to station 9+65 and the disintegration had extended deeper on the south side from station 10+60 to station 10+80. In September, 1916, the surface east of a house connection near station 10+80 was replaced with a 2-inch surface of Topeka asphaltic concrete.

*Experiment No. 5—Cut-back oil-asphalt, mixing method.*—In September, 1916, the surface of this section, except the easterly 100 feet, was rebuilt with Topeka asphaltic concrete. The surface on the easterly 100 feet was in fair condition, except along the sides and the center from station 13+25 to station 13+40, where the seal coat had worn through and several potholes had formed.

*Experiment No. 6—Oil-asphalt, penetration method.*—In the spring of 1916 two small potholes about 7 feet north of the center at stations 13+97 and 14+13, and two small potholes at the junction of experiments Nos. 6 and 7 were patched with broken stone and asphaltic cement. No other repairs were made on the section during the year. The seal coat was worn through in a number of places and potholes were developing on the north side at stations 15+40 and 15+45, where the foundation had been poor. From station 13+94 to station 14+38 the surface was disintegrated slightly.

*Experiment No. 7—Refined coal tar, penetration method.*—Potholes have formed in the surface from station 15+57 to station 16+95. The south edge from station 16 to station 17 was in poor condition. The seal coat was becoming very thin. This section was less wavy than any of the other sections and, on the whole, was in good condition.

*Experiment No. 8—Fluxed native asphalt, penetration method.*—The slight waviness of the surface was a little more pronounced than at the previous inspection. The small pothole at station 17+60 had disappeared but a depression still was noticeable. On the whole this section was in very good condition.

*Experiment No. 9—Oil asphalt, penetration method.*—The surface was raveled to a depth of about one-half inch or more in a number of places scattered throughout the section. At the easterly end the surface abutting the wood-block pavement was particularly bad in this respect. This probably was due to a slight difference in grade elevation for the two surfaces.

## RÉSUMÉ OF PREVIOUS REPORTS.

### OIL-CEMENT CONCRETE, OIL ASPHALT, TAR, AND FLUXED NATIVE ASPHALT.

This experimental road, 25 feet wide, was built in August and September, 1911. The work consisted in resurfacing a 2,000-foot length of badly worn, water-bound macadam pavement on Hillside Avenue. Before the experimental work was begun the old macadam surface was scarified and rebuilt to a crown of three-eighths inch per foot by addition of material and rolling. On this macadam as foundation nine experimental surfaces were laid—one oil-cement concrete pavement, four bituminous concrete pavements, and four bituminous macadam pavements. The aggregates used in all the experiments was clean, crushed trap rock, screened according to the following grades.

*Screenings*—Crusher run passing a ⅝-inch circular opening including dust of fracture; *¾-inch stone*, passing 1¼-inch circular opening and retained on ⅝-inch opening; *1½-inch stone*, passing 2¼-inch circular opening and retained on 1¼-inch opening; *⅜-inch stone* screenings from which dust had been removed.

Traffic census for 11 days in 1911 showed a maximum of 2,794 vehicles per day of 24 hours, a minimum of 655 vehicles per day of 24 hours, an average of 1,493 vehicles per day of 24 hours.

Table 67 indicates the method of construction of the experimental sections and shows their condition at the time of several inspections since construction. The tabulation shown has been prepared from detail reports of inspection and published in Circulars Nos. 98 and 99, Office of Public Roads, and in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture.

TABLE 67.—*Condition record of experimental road sections at Jamaica, N. Y.*

| Section No. | Length. | Description of original construction, 1911 (Office of Public Roads Circular No. 98). | Condition May 1912 (Office of Public Roads Circular No. 99). | Condition June, 1913 (U. S. Dept. Agr. Bul. No. 105). | Condition Jan., 1915 (U. S. Dept. Agr. Bul. No. 257). | Condition Jan., 1916 (U. S. Dept. Agr. Bul. No. 407). |
|---|---|---|---|---|---|---|
| | *Feet.* | | | | | |
| 1 | 173 | *Oil-cement concrete.*—Proportion by volume, 1 Portland cement, 2 sand, 4 crushed trap rock, and residual oil to the amount of 10 per cent by weight of the cement; coarse aggregate ¾-inch maximum to ¼-inch minimum; one layer 4 inches thick, with addition of trap-rock screenings on the tamped surface for the first 12.5 feet; the remaining surface covered with mixture made in the proportion of 2 bags cement, 2.5 feet sand, 7.5 screenings, and 8 quarts oil. | Surface had small worn areas ranging from a few square inches to 2 or 3 square feet; entire concrete surface coated with a bituminous seal coat, using different types of bitumen; also worn places repaired with bitumen and stone chips. | The various carpet coats had worn off, except about 75 per cent of the refined coal-tar portion; section given a seal coat of different bituminous material; many deep depressions which had formed were repaired. | Repair of bare spot had been made in 1914, surface in very good condition, except for about 20 bare spots. | Bituminous surface treatment worn away in many places; concrete worn and potted in places. |
| 2 | 299 | *Cut-back oil-asphalt, mixing method.*—Compacted depth 2 inches; proportion—7.5 cubic feet, ¾-inch stone to 5.5 gallons of bitumen; bitumen heated to 240° F.; stone dried; surface finished with seal coat and ⅜-inch stone; seal coat bitumen applied by means of distributer; rainy weather during construction retarded progress. | Surface in good condition, except at station 4+94; depression due to a yielding of the foundation; this place was repaired; from station 1+98 to 4+50 the surface was rough and wavy, but unbroken; this part had not been repaired. | From station 1+98 to station 4+50, scarified and rolled; new seal coat of refined coal tar applied at the rate of 0.53 gallons per square yard; remaining section was slightly wavy in surface; no repair made. | In May, 1914, entire surface scarified to depth of 3 inches; about one-third of bituminous material raked off; surface rolled and covered with ¾-inch stone; rolled, covered with thin layer of chips, and opened to traffic. | Section entirely scarified in October, 1915, except for the easterly 50 feet; shaped and rolled and surfaced with 2-inch asphaltic concrete prepared according to the Topeka specifications; easterly 50 feet in fair condition. |
| 3 | 304 | *Fluxed native asphalt, mixing method.*—Other features same as in section No. 2, except bitumen heated to 340° F. Also seal coat applied by means of hand pouring pots; bad weather during construction. | Excellent condition, except at station 5+00 a slight depression due to wear; repaired by applying an oil-asphalt seal coat. | Slightly wavy; otherwise in excellent condition. | All in good condition, except in places where house sewer connections were made. | Same as when last inspected. |
| 4 | 298 | *Refined coal tar, mixing method.*—Proportion, 10 cubic feet stone to 7 gallons bitumen; in the seal coat, coal tar was used for the first 150 feet, oil-asphalt for the remainder; other features as shown in section No. 3. | Seal coat of oil-asphalt in good condition; seal coat of refined coal tar entirely worn off; new seal coat of light coal tar at the rate of 0.28 gallon per square yard applied from station 8+00 to station 8+70 and from station 8+70 to station 9+50; seal coat of tar-asphalt preparation applied. | Slightly wavy; otherwise in excellent condition. | Section in excellent condition, except for wavy surface in places and for a few small spots where seal coat is worn off. | Wavy on sides; center in good condition; on south side surface crumbling where seal coat has been worn off. |

TABLE 67.—*Condition record of experimental road sections at Jamaica, N. Y.*—Continued.

| Section No. | Length. | Description of original construction, 1911 (Office of Public Roads Circular No. 98). | Condition May 1912 (Office of Public Roads Circular No. 99). | Condition June, 1913 (U. S. Dept. Agr. Bul. No. 105). | Condition Jan., 1915 (U. S. Dept. Agr. Bul. No. 257). | Condition Jan., 1916 (U. S. Dept. Agr. Bul. No. 407). |
|---|---|---|---|---|---|---|
| | *Feet.* | | | | | |
| 5 | 296 | *Cut-back oil-asphalt, mixing method.*—Same as in section No. 2, excepting proportion was changed so as to use 10 cubic feet of stone to 7 gallons bitumen, the bitumen was a similar type of material, but was obtained from another manufacturer, and seal coat was applied by means of pouring pots. | In good condition, except for two holes at station 13+37, these filled with Topeka asphalt paving mixture. | General surface good; several holes worn through surface; repaired. | Section is wavy; seal coat is wearing off and pot holes are forming. | West end badly worn; should be rebuilt, other part less worn, but also in need of repair. |
| 6 | 156 | *Oil-asphalt, penetration method.*—A single course of 1½-inch stone spread to a loose depth of 3 inches; rolling followed by an application of oil-asphalt at the rate of 1½ gallons per square yard; surface covered with ⅜-inch stone chips and rolled; a seal coat with the penetration material and ⅜-inch stone chips used on eastern one-half; cut-back oil asphalt used for seal coat on western half. | In good condition, except for damage done by steel-tired trucks; damage repaired. | In excellent condition; two grades of oil asphalt used for seal coat; apparent that the heavy is the better. | Section in good condition, except that seal coat is wearing off. | Same condition as at time of last inspection, except sides are becoming wavy. |
| 7 | 150 | *Refined coal tar, penetration method.*—Bitumen applied at temperature of 260 to 270° F., with distributor; other features as shown in section No. 6. | In good condition, except for slight break in seal coat due to trucks described in No. 6; damage repaired with tar asphalt and sand. | General surface good; several holes worn through surface; repaired. | Seal coat wearing off on edges; a few pot holes are forming; otherwise in good condition. | Good condition, except for a strip 5 feet wide along south side, where surface is disintegrating. |
| 8 | 150 | *Fluxed native asphalt, penetration method.*—As used in section No. 3; temperature 330° F.; other features as shown in section 7, including use of distributor. | Surface quite soft in early summer; damaged by trucks previously mentioned; damage repaired by tar asphalt and sand. | In good condition.......... | Slight waviness developing over entire surface. | Same as at time of last inspection, except for one hole which is developing. |
| 9 | 150 | *Oil-asphalt, penetration method.*—Other features as shown in section No. 8.................. | Seal coat had been picked up in a few places by the steel-tired trucks; this damage was repaired; the surface was depressed at station 19+25 over on old sewer trench; this was repaired. | In good condition, except for one hole; this repaired. | Seal coat worn off in places; few pot holes developed; otherwise in good condition. | Same as at previous inspection, except that seal coat is wearing off in one place. |

## AMES, IOWA, 1910.

### OIL-ASPHALT GRAVEL.

### Résumé of Previous Reports.

This experimental road was built in September, 1910. The work consisted in resurfacing a 300-foot section of gravel road in the grounds of the Iowa State Agricultural College. The old gravel road had a thickness of 6 inches and was in good condition when the work was begun. A portion of the traffic was automobile. Table 68 shows the condition of the experiment at various times since its construction. The results shown have been taken from the reports of inspection made by this office, published in Circulars Nos. 94, 98, and 99, Office of Public Roads, and in Bulletins 105, 257, and 407, U. S. Department of Agriculture.

TABLE 68.—*Experiments at Ames, Iowa.*

| Length | Description of original construction, 1910 (Office of Public Roads Circular 94). | Condition November, 1911 (Office of Public Roads Circular No. 98). | Condition October, 1912 (Office of Public Roads Circular No. 99). | Condition January, 1914 (Bulletin No. 105, U. S. Dept. Agr.). | Condition December, 1914 (Bulletin No. 257, U. S. Dept. Agr.). | Condition December, 1915 (Bulletin No. 407, U. S. Dept. Agr.). |
|---|---|---|---|---|---|---|
| *Feet.*<br>300 | *Oil-asphalt gravel.*—Oil asphalt at 300° F., applied to a loose gravel surface at the rate of 1½ gallons per square yard; when asphalt had become cold surface was saturated thoroughly with water and harrowed; surface rolled when it had dried out; width of the surface 27 feet; crown, one-half inch to 1 foot. | Surface uniform throughout, about 1 inch of mud carried on it from adjoining road. | More travel on east side; this has the smoothest surface; hole dug in center of road shows bitumen 3 inches deep below surface. | Good condition, two or three depressions; surface resembles a brown layer of packed gravel and old bituminous material which is friable. | Generally in good condition; surface has been reshaped and treated with a light oil; effect not yet apparent. | Light oil again applied in June, but unsuccessful; in October heavy asphalt oil applied to the traveled portion at rate of one-half gallon to square yard; in good condition at time of this inspection. |

## KNOXVILLE, TENN., 1910.

### TAR AND OIL PREPARATIONS.

### RÉSUMÉ OF PREVIOUS REPORTS.

This experimental road was built in the summer of 1910. The work consisted in resurfacing a section of the Rutledge Pike, an old, badly worn, water-bound macadam. Before the experimental work was begun the old macadam surface was loosened and reshaped. Crushed limestone ranging from 2 inches to three-quarter inch in diameter was spread over the road to a depth of 2 inches, and rolled. A crown of one-half inch to a foot was used for both the foundation and the surface. On this macadam as foundation, three experimental surfaces, 20 feet in width, were laid, using bituminous materials by the penetration method. A very hard limestone, known locally as iron limestone, was used in the wearing course of all the experiments. The following table indicates the method of construction and shows the condition of the experimental sections at the time of the several inspections. The tabulation has been prepared from reports made by this office and published in Circulars Nos. 94, 98, and 99, Office of Public Roads, and in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture.

TABLE 69.—*Condition of experiments at Knoxville, Tenn.*

| Section No. | Length. | Description of original construction in 1910 (Office of Public Roads Circular No. 94). | Condition November, 1911 (Office of Public Roads Circular No. 98). | Condition January, 1913 (Office of Public Roads Circular No. 99). | Condition December, 1913 (Bulletin No. 105, U. S. Dept. Agr.). | Condition November, 1914 (Bulletin No. 257, U. S. Dept. Agr.). | Condition December, 1915 (Bulletin No. 407, U. S. Dept. Agr.). |
|---|---|---|---|---|---|---|---|
| 1 | *Feet.*<br>217 | *Refined coal tar, penetration method*—*Wearing course.*—Hard, clean limestone, ranging in size from 2 inches to three-fourths inch; Loose depth 4 inches; rolled until firm; binder at a temperature of 250° to 300° F., applied at the rate of 1½ gallons per square yard; ½-inch size screenings applied; surface rolled; seal coat of penetration material at rate of one-half gallon per square yard, followed by addition of screenings. | Seal coat worn off; otherwise in good condition; surface hard and smooth; harder than No. 3. | Surface raveled and numerous depressions; section will be resurfaced in the spring. | Section was not resurfaced, as was expected, and now has appearance of a plain macadam. | Section worn out; serves no further purpose as an experiment. | Failed completely. |
| 2 | 590 | *Refined tar preparation, penetration method.*—Constructed in same manner as No. 1, with exception that a different binder was used; the binder was a refined mixture of coal tar and water-gas tar. | Same condition as section No. 1, except not quite such a Mosaic appearance and seal coat not worn to same extent. | Eastern half of section in good condition; western half has several raveled areas. | About one-half of seal coat worn off; surface uneven; surface broken for several water mains; not properly repaired. | Surface covered with holes and depressions; this section should be reconstructed. | Do. |
| 3 | 173 | *Asphalt, penetration method.*—Constructed in same manner as No. 1, with exception that an oil-asphalt was used for a binder. | In good condition; surface softer than in sections Nos. 1 and 2 and has the appearance of sheet asphalt; depressions at the east end of the section. | Practically same condition as at time of last inspection. | Surface smooth and hard; in very good condition. | Except for a few depressions on west side, this section is in excellent condition. | In good condition. |

## YOUNGSTOWN, OHIO, 1909.

### SLAG, SLAG AND LIME, SLAG AND WASTE SULPHITE LIQUOR PREPARATION, AND SLAG AND TAR.

The original report describing these experiments was published in Office of Public Roads Circular No. 92, and subsequent reports of annual inspections in Circulars Nos. 94, 98, and 99, and in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture. The following report describes the condition of the various experiments on December 4, 1916, and furnishes a brief résumé of previous reports. The experiments are discussed in the order of their section numbers, beginning at Mahoning Avenue.

*Section No. 1, blast-furnace slag*—The condition of this section was unchanged materially since the inspection in December, 1915, except that the middle of the road was no longer pulverized, and pronounced depressions about 2 inches deep have developed in the wheel tracks at about 150 feet and 175 feet from the north end. A hole dug about 200 feet from the north end of the section showed the depth of slag to be about 8 inches. A laboratory examination of a sample of this slag showed (1) that the slag particles were carbonated on the surface and (2) a cementing value of 55.

*Section No. 2, blast-furnace slag and lime*—The south one-half of this section showed two wide, shallow ruts, with a slight accumulation of fine loose material along both edges of the road, and over this part of the section the crown of the surface had disappeared almost entirely. The remainder of the section had not changed materially in appearance since the inspection of December, 1915, except that the ruts had become slightly more pronounced and a few of the foundation stones were showing in the surface. Holes dug at 125 feet from the north end and 30 feet from the south end showed the depth of slag to be 6½ inches. A sample of this slag showed (1) that the slag particles were carbonated on the surface and (2) a cementing value of 115.

*Section No. 3, blast-furnace slag and waste sulphite liquor preparation*—The north end of this section, for a distance of 100 feet, was resurfaced with slag sand in the fall of 1916. The next 100 feet showed a rather loose surface with two broad, shallow ruts, though the depression along the center of the road noted in December, 1915, had almost disappeared. The remainder of the section (300 feet) was worn uniformly and in good shape, except for depressions in the ruts near the middle of the section, which cover an area of about 2 square yards, and the west edge of the road had been partially destroyed to a width of about 1 foot for a distance of about 100 feet from the south end. The latter damage was caused by failure to maintain the shoulders in proper shape. The south end of the section was worn down about 2½ inches below the surface of section 4, where a bituminous binder was used.

Holes were dug at 225 feet from the north end and 175 feet from the south end of the section and showed the depth of the slag to be about 6½ inches. A sample of the slag showed (1) that the slag particles were carbonated on the surface, (2) that the pores of the slag contained calcium hydrate crystals, (3) a cementing value of 63.

*Section No. 4, blast-furnace slag and refined coke-oven tar*—The south 50 feet remained in good condition, except that the surface was slightly wavy. The remainder of the section, which was reported as having failed at the time of the inspection of December, 1915, had been covered over with slag sand, and is no longer of experimental value. A sample of the new slag sand showed a cementing value of 67.

*Section No. 5, blast-furnace slag*—The south 90 feet of this section was in uniformly good shape. The remainder of the section, through the cut, was worn into ruts and showed an accumulation of fine material on the surface. The ruts noted at the time of the inspection of December, 1915, 165 feet and 135 feet, respectively, from the south end, had increased in depth to about 3 inches. For the rest of the distance the ruts were broad and shallow. The north end of the section still was about 1½ inches below the surface of section 4.

*Section No. 6, blast-furnace slag*—This section had not changed in appearance since the inspection of December, 1915, except that an accumulation of fine material had collected along the east edge of the road. A hole dug about 150 feet from the south end of the section showed the depth of the slag to be about 9½ inches. A sample of the slag showed (1) that the particles of slag were carbonated on the surface and (2) a cementing value of 45.

*Section No. 7, blast-furnace slag and open-hearth slag*—The north one-third showed little evidence of wear and the surface was firm and well bonded. The south one-third showed considerable wear along the wheel tracks, but the top course did not appear to have worn through, and the surface still was firm and well bonded. The depression over the culvert near the south end had flattened out, due to the wearing action of traffic, but had not been repaired. The middle one-third of the section was resurfaced with slag sand in the fall of 1916, and probably will not be of any further service as an experiment. It was evident that the surface had become rather rough and badly rutted before the slag sand was applied.

Holes dug at 50 feet and 100 feet from the south end showed the depth of the slag to be about 9 inches. A sample of the slag showed a cementing value of 65, carbonated surfaces, and practically no evidence of the open-hearth screenings used in the original construction.

TABLE 70.—*Experiments at Youngstown, Ohio.*

| Section No. | Length. | Description of original construction. | Condition Jan. 27, 1911, just after thaw. | Condition Dec. 10, 1911. | Condition Dec. 11, 1912. | Condition Sept. 1, 1913. | Condition Oct. 26, 1914. | Condition Dec. 3, 1915. |
|---|---|---|---|---|---|---|---|---|
| 1 | *Feet.*<br>500 | Regular macadam method; first course, 9 inches loose; size of particles, 1½ to 3½ inches; second course, 4 inches at center, 2½ inches at edge, loose; finished with screenings, water, and rolling. | Surface in good condition and free from raveled spots. | Surface smooth in wheel tracks, loosened in middle of road; better than section No. 5, but not so good as section No. 6. | Surface in excellent condition, except north 50 feet, which had been scarified shortly before inspection; slight evidence of wheel ruts entirely due to wear of traffic. | Surface firm and well bonded and crown intact; foundation slag only very slightly in evidence. | Same as preceding report, except that well-defined shallow ruts have developed and there are three depressions where binder has disappeared. | Same as preceding report, except middle of road slightly more worn and pulverized. |
| 2 | 500 | Same as section No. 1, except 5 per cent of powdered quicklime was mixed with screenings by hand; bonded very quickly on being sprinkled and rolled. | Surface somewhat raveled and scarcely better than sections 5 and 6; not so good as section 1; reported to have been better in summer. | Substantially the same as section No. 1. | In good condition, except for slight evidence of ruts as in section No. 1. | Same as section No. 1, except foundation slag slightly more in evidence and slight ruts in traveled way. | Same as preceding report. | Same as section No. 1, except ruts slightly deeper and surface slightly more worn. |
| 3 | 500 | Same as in section No. 1, except waste sulphite liquor used in bonding top course and screenings at rate of 1 gallon per square yard; road cracked and blistered on being opened to traffic and was rebonded, using water. | Better than section 1, but not so well bonded as section No. 7. | Good appearance and slightly better bonded than section No. 6. | Surface covered with thin coating of clay, due to grading operation on west side of road; appearance otherwise very good, and there is no evidence of raveling. | Same as section No. 2. | Same as section No. 2, except that south half of section shows slightly less evidence of wear. | North one-half same as section No. 2; south one-half better preserved. |
| 4 | 300 | First course same as section No. 1; second course, 4 inches deep, loose, 3 parts slag, 1½ inches to ¾ inch, 1 part slag, ⅜ inch to dust, 6 per cent coke-oven tar, all heated and hand mixed; seal coat, ¼ gallon tar to square yard and screenings; total tar 1½ gallons to square yard. | Surface perfectly bonded with mosaic appearance; fresh fill had settled, causing irregularities in surface, but no damage to bond. | Surface in excellent shape, except for several loose spots at 80 and 100 feet from north end, where fill has settled. | North and south thirds present good appearance; middle third, on fill, has settled unevenly and disintegration is following; apparent shortage of tar at some points. | Shows from 1½ to 2 inches less wear than adjoining sections; evidence of disintegration has not increased since last report. | Same as 1912 inspection, except that evidences of failure have increased, especially in middle third. | South 50 feet still intact and presents smooth, well-bonded surface; rest has failed because of foundation settlement. |

TABLE 70.—*Experiments at Youngstown, Ohio*—Continued.

| Section No. | Length. | Description of original construction. | Condition Jan. 27, 1911, just after thaw. | Condition Dec. 10, 1911. | Condition Dec. 11, 1912. | Condition Sept. 1, 1913. | Condition Oct. 26, 1914. | Condition Dec. 3, 1915. |
|---|---|---|---|---|---|---|---|---|
| 5 | *Feet.*<br>300 | Single course, 12 inches at center, 9 inches at edge, loose; slag ¾ inch to 3½ inches in size; surface finished with screenings, water, and rolling; much rolling necessary. | Center of roadway badly raveled; soft spot in center of road near middle of section. | Surface smooth in wheel tracks, loosened in middle of road; reported to have been practically dustless during preceding summer. | Ruts more apparent than on other sections, but no evidence of raveling; section has worn down about 1½ inches below section No. 4 where they join. | Slightly dusty; large stones showing in surface; shallow ruts in traveled way. | North two-thirds in cut appears to have been damaged by softening of foundation, due to lack of subdrainage, and is worse rutted than any other of the sections; south one-third in good condition. | North two-thirds same as preceding report; south one-third has developed ruts and two depressions. |
| 6 | 325 | First course, 9 inches deep, loose, slag 3½ inches to dust; second course, 6 inches at center, 4 inches at edge, slag 3½ inches to ¾ inch; rolled and finished same as section No. 1. | Center of road badly raveled; slightly better than section No. 5, but not so good as section No. 1. | Similar to Nos. 1 and 5, except slightly better. | In fair condition, except for slight ruts; surface covered with film of dust, but no evidence of raveling. | Same as section No. 5, except larger stones are showing in surface, and there are several shallow worn places. | Same as preceding report, except that wear is more evident in ruts, as well as other depressions. | Same as preceding report. |
| 7 | 325 | Same as section No. 6, except screenings were of open-hearth slag, ¼ inch to dust; spread 1½ inches deep, loose; when puddled and rolled a firm surface was quickly produced. | Surface very firm and well bonded; few small holes caused by soft particles of slag; condition second only to section No. 4. | Slight unevenness for 100 feet at north end over fill; otherwise same as preceding report; second only to section No. 4. | Fair condition, except for slight ruts and film of dust which produces mud when wet; slight settlement over culvert. | Same general appearance as sections Nos. 5 and 6; settlement over culvert has increased. | Surface swept during preceding summer has not raveled; ruts 2 and 3 inches deep in places; depression over culvert increased. | Surface firm and well bonded and harder than any other section, except south 50 feet of section No. 4. |

These experiments have now been under way for about seven years, and the salient features of the records are summarized below for convenience.

The total length of the experimental road is 2,750 feet, and the width of the slag surface 14 feet. The blast-furnace slag was obtained from the Youngstown plant of the Carnegie Steel Co., and had weathered on the dump for some time. The slag was selected with care and was screened to the sizes indicated for the different sections. The open-hearth slag was obtained from the ordinary basic open-hearth process and was ground to the size indicated. The tar was a refined coke-oven tar, and the waste sulphite liquor was a concentrated form of the ordinary by-product in the manufacture of wood pulp. The traffic over the road is only moderate, but no actual counts have been taken.

## GARDEN CITY, DODGE CITY, BUCKLIN, AND FORD, KANSAS, 1908.

### SAND-CLAY.

The original report of these experiments appeared in Circular No. 90, and reports of subsequent inspections in Circulars Nos. 92, 94, 98, and 99, Office of Public Roads, and in Bulletins Nos. 105, 257, and 407, U. S. Department of Agriculture.

*Experiment at Garden City.*—This road was inspected December 9, 1916. The ruts and low places mentioned in the last report had been repaired by the addition of new material and by the liberal use of the road drag. The road had been resurfaced for a distance of 600 feet between station 6 and the bridge across the Arkansas River. There had been no rain since this work was done, and because of a lack of moisture the surface was not very well bonded. In general, this experiment was in a good condition.

*Experiments at Bucklin.*—This road was inspected December 8, 1916. Its condition, in general, was very poor. The surface was badly rutted and had worn very thin in places. From station 46 to the bridge it had been badly damaged from flood water of the Arkansas River in the spring of 1915. This section had been rebuilt and surfaced and was in good condition except that the surface was very poorly bonded. The summer had been exceptionally dry and very little improvement had been made by using the road drag in maintenance.

*Experiment at Ford.*—This road was inspected December 8, 1916, and was in good condition generally. The low places and ruts mentioned in the last report had been properly repaired. The surface was very smooth and well bonded.

These experimental sand-clay roads have led, either directly or indirectly, to the construction of many similar roads in that part of the country. According to statistics gathered by the Office of Public

Roads and Rural Engineering, United States Department of Agriculture, in 1914 Kansas alone had more than 750 miles of road surfaced with sand-clay, which was almost three-fourths of the total mileage of improved roads in the State. It seems, therefore, that these experiments have served their purpose entirely, and they will not be reported on again.

## BOWLING GREEN, KY., 1907.

### KENTUCKY ROCK ASPHALT.

The original report of this experiment was published in Circular No. 89 and reports of subsequent inspections in Circulars Nos. 90, 92, 94, 98, and 99, and Bulletins Nos. 105, 257, and 407 United States Department of Agriculture. The following report relates to the condition of the pavement on January 6, 1917. This work had not been repaired or cared for in any way since its construction. The failure of the surface was most marked in the west 150 feet. On the north side of this section the surface failed for one-third the width of the road and the remaining area was covered with holes. The next 150 feet had several large worn areas and numerous pot holes. The surface of the remaining portion still was intact and where the binder had not failed the surface was smooth and hard. Generally speaking, the condition of this experimental road would not warrant any repairs in the future.

### RÉSUMÉ OF PREVIOUS REPORTS.

A series of experimental road sections were constructed in 1907, for the purpose of determining the fitness of Kentucky rock asphalt and crude Kentucky oil on binders in macadam construction and also to determine the comparative value of a residuum oil preparation and crude oil as dust preventives. The following table indicates the method of construction and shows the condition of experimental sections at the time of several inspections. The tabulation has been prepared from reports of inspections made by this office, published in Circulars Nos. 89, 90, 92, 94, 98, 99, and in Bulletins Nos. 105, 257, and 407, United States Department of Agriculture.

TABLE 71.—*Experiments at Bowling Green, Ky.*

| Experiment No. | Length. | Description of original construction, 1907. | Condition January, 1909. | Condition May, 1909, after heavy rains. | Condition December 21, 1910. | Condition November 23, 1911. | Condition January 10, 1913. | Condition January 5, 1914. | Condition November 5, 1914. | Condition December 13, 1915. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Feet.*<br>385 | *Rock asphalt.*—Scarified gravel base, 4-inch limestone, loose, rolled once to smooth; 1½-inch fine crushed rock asphalt; finished by thorough rolling. | Road smooth, free from ruts, limestone showing in only two small places which were perfectly bonded; at one place shoulders had settled slightly. | Surface clean, smooth, and compact; no ruts; surface course of rock asphalt worn down in places to crushed stone, but stones were tightly bound. | (Light rains alternating with freezing weather for 10 days preceding.) Smooth and hard generally; eastern half shallow ruts about 2 feet from edges, indicating insecure shoulders; one small hole 100 feet from eastern end. | Surface hard, firm, fairly smooth, well bound; small hole mentioned in last report now about 1 foot in diameter. | Surface generally intact, smooth, and hard; hole at east end not yet repaired; three small worn places at 3, 25, and 45 feet, respectively, from west end; disintegrated asphalt; also three shallow depressions in crown at middle of section. | For 50 feet from west end north half badly worn and rock asphalt over half gone; south half in fair condition; 33 depressions in remainder of section, showing that disintegration has been quite rapid during the year. | No maintenance, and accumulation of dirt on surface. No great change in condition. In places practically all asphalt has disappeared. | No repairs; area of defects materially increased. |
| 2 | 631 | *Oil penetration.*—Gravel road; rather flat crown; application of heavy oil, mixture of residual oils; average 0.9 gallon per square yard; applied with gravity sprinkler. | Section had been covered with gravel, and no result was obtained from its use. | | | | | | | |

TABLE 71.—*Experiments at Bowling Green, Ky.*—Continued.

| Experiment No. | Length. | Description of original construction, 1907. | Condition January 1909. | Condition May, 1909, after heavy rains. | Condition December 21, 1910. | Condition November 23, 1911. | Condition January 10, 1913. | Condition January 5, 1914. | Condition November 5, 1914. | Condition December 13, 1915. |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | *Feet.*<br>3,312 | *Crude oil on gravel.*—Same base as section 2. Application, crude oil. Average, 0.84 gallon per square yard. | Use of crude oil of only temporary effect. No trace of oil apparent. According to report, oil acted as a successful temporary dust preventive. | | | | | | | |
| 4 | 1,089 | *Crude oil on macadam.*—Macadam road on Telford base; crown slightly more than 1 inch per foot; good repair. Application, crude oil. Average, 0.52 gallon per square yard. | Same as experiment 3. | | | | | | | |

UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 587**

**Joint Contribution from the Bureau of Plant Industry**
**WM. A. TAYLOR, Chief, and the Bureau of**
**Markets, CHARLES J. BRAND, Chief**

**Washington, D. C.** ▼ **September 8, 1917**

# THE HANDLING AND STORAGE OF APPLES IN THE PACIFIC NORTHWEST.

By H. J. RAMSEY, *Pomologist in Charge, Fruit Handling and Storage Investigations;* A. W. McKAY, *formerly Pomologist,* and E. L. MARKELL and H. S. BIRD, *formerly Scientific Assistants, Office of Horticultural and Pomological Investigations.*[1]

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## IMPORTANCE OF COLD STORAGE.

According to the census reports of 1910 there were at that time 6,044,918 apple trees of bearing age and 8,643,228 apple trees of nonbearing age in the States of Oregon, Washington, and Idaho. The production in bushels for 1909 is given as 5,262,985, as compared with 1,826,620 bushels 10 years before. In 1913 the apple crop for the four counties of Chelan, Douglas, Okanogan, and Grant, in the State of Washington, was conservatively estimated at 4,328 carloads.

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[1] B. B. Pratt, formerly Pomologist; C. W. Mann, Pomologist; K. B. Lewis, formerly Scientific Assistant; George W. Dewey, W. C. Quick, V. W. Ridley, Carl E. Schuster, and E. D. Vosbury, Scientific Assistants in the Office of Horticultural and Pomological Investigations, were actively engaged in the prosecution of these investigations at various times during the period covered by the work.

NOTE.—The fruit and vegetable handling, transportation and storage investigations formerly administered in the Office of Horticultural and Pomological Investigations, Bureau of Plant Industry, are now being prosecuted jointly and cooperatively by the Bureau of Plant Industry and the Bureau of Markets.

This is approximately equal to the 2,672,100 bushels which, according to the census, comprised the entire apple crop of the whole State of Washington in 1909. The production has increased greatly, not only in the counties mentioned but also in Yakima, Spokane, Klickitat, and other counties in Washington, in the Hood River and the Rogue River valleys of Oregon, in eastern Oregon, in the Bitter Root Valley of Montana, and in southwestern Idaho.

The total car-lot shipments of apples from the four States of Oregon, Washington, Idaho, and Montana for the 1915–16 shipping season amounted to approximately 11,166 cars. The total car-lot shipments from these States for the shipping season 1916–17 to March 19, inclusive, amounted to 16,625 cars. The shipments of apples still in storage at that time would increase this amount considerably.

The proportion of each year's crop from these States that is placed in cold storage, either at points of production or in the East, is somewhat difficult of determination. The actual storage holdings necessarily will fluctuate each season with the production, market conditions, and prices. In 1911 something over 225,000 boxes were held in either common or cold storage in the three States first mentioned, as compared with almost 1,000,000 boxes in cold storage in 1914. These figures are indicative of the increasing importance of cold storage in the successful distribution and disposal of the northwestern apple crop. No reliable figures are obtainable regarding the amount of the crop produced in the Northwest and stored in Middle Western and Eastern States during the last few years. Storage facilities in the producing States of the Pacific Northwest are adequate for only a small proportion of the crop. As a considerable proportion of the production consists of late fall and winter varieties, it is obvious that by far the greater portion of the crop must be held in storage for shorter or longer periods either in the producing States or in the East and Middle West. Whether these holdings are the property of the growers, the shippers, or the buyers does not minimize the importance of cold storage in the profitable production and disposal of the northwestern apple crop.

The rapid increase in acreage and production of apples in the Northwestern States has made the wide distribution and profitable marketing of the northwestern apple crop a problem second in importance only to the successful growing of the crop. Cold storage permits a wider and more equitable distribution of apples than is possible when it is not employed, and it extends the season during which apples may be marketed in good condition. Any system which aims at an equitable and economic distribution of the northwestern apple crop must employ cold-storage facilities for the successful preservation for a longer or shorter period of a considerable proportion of the crop. It is therefore of the utmost importance that growers, shippers, warehousemen, and all others concerned in the growing, transportation, or marketing of the apple crop know accurately and definitely (1) what constitutes proper storage facilities, and (2) how the fruit should be handled, both in harvesting and in storage, in order that it may possess when marketed and offered to the consumers the maximum of good condition and quality.

Unless the apple crop can be successfully held in good condition until it reaches the consumer, all other questions and factors are negligible.

## FUNCTION OF COLD STORAGE.

For a proper understanding of the behavior of apples in storage it must be kept clearly in mind that the apple, like all fruits, is a living organism and that its life cycle, which begins in the blossom, ends under natural conditions in the death and decay of the fruit. When the fruit is picked from the tree its life processes do not stop. On the contrary, at ordinary temperatures, they continue as rapidly or possibly even more rapidly than before. The function of cold storage is primarily to retard these life processes. Its purpose is also to retard and prevent the germination of spores of fungi which cause the fruit to decay, and to prevent the development of skin blemishes. For this purpose a temperature of between 31° and 32° F. is considered standard for the apple. No temperature, however, which will not seriously injure the fruit by freezing can entirely check its ripening processes or the growth of all fungi which cause decay. It is obvious, therefore, that fruit allowed to become overripe prior to storage can never regain in cold storage the quality and vitality it has lost. Neither can cold storage prevent the final decay of fruit already infected with decay fungi. Since cultural and handling methods largely determine the condition of the fruit when it is stored, the first responsibility for its successful storage lies with the grower and shipper.

## EXPERIMENTS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

In 1911 the Bureau of Plant Industry began an investigation of factors governing the behavior of northwestern apples in cold storage. Fruit for this purpose was obtained from the Rogue River and Hood River valleys of Oregon, and from the Yakima and Wenatchee sections of Washington. A considerable amount, also, was obtained from other sections in Washington, Idaho, and Montana. Between 500 and 600 boxes of apples were used each season in the experiments, and as each box was picked and packed by a bureau representative or under his immediate supervision, it has been possible to obtain an exact history of each box stored and also a record of the soil in which it was grown, the condition of the trees, and the cultural methods pursued.

Although the investigations have been comprehensive in scope, so many factors affect the behavior of fruit in storage that the data obtained are still too limited to justify a complete report or definite recommendations with reference to all the factors involved. Certain important practices, however, have been shown to have such a consistent and important bearing on the successful storage of northwestern apples that it is believed advisable to present to the industry at this time the data obtained. No attempt is made to discuss all phases of the problem. The discussion is limited largely to those factors of first importance to the industry on which it has been possible to secure reliable and consistent data over a period of four years.

The data given cover in most cases the seasons 1911–12, 1912–13, 1913–14, and 1914–15.

## OUTLINE OF EXPERIMENTS.

(1) A determination of the influence of maturity at time of picking on the keeping quality of the more important varieties grown in the Northwest.

Two pickings from the same trees were made 20 days apart. Frequently an additional pick was made between these two. The first, or immature, pick was made at the beginning of the commercial picking season for the variety. The last, or mature, pick was made 20 days after the first, usually a few days later than the last commercial picks. These lots, comparable in every other respect, were stored immediately at a temperature of between 31° and 32° F. All fruit was stored in Portland, Oreg. Careful inspections were made four times during the winter, beginning in all but the early varieties about the first of January and continuing at intervals approximately six weeks apart. One-fourth of each lot was taken out of storage at each withdrawal, inspected, and held in an ordinary warehouse room for 10 days. It was then inspected again and discarded. The temperature of the fruit during these 10-day periods varied with the season and climatic conditions, but was usually between 50° and 60° F.

(2) A study of the effect of delaying the storage of certain important commercial varieties on their behavior in storage.

For this purpose several boxes of a variety were picked and packed at the same time. Half of each series was placed in cold storage as soon as possible, usually not more than two days from the time of picking; the other half was held two weeks in a grower's or shipper's warehouse before being placed in cold storage. The first lot was designated "Immediate"; the second, "Delayed." Both lots were stored at 31° to 32° F. and inspected four times during the winter, as in the case of the fruit for the maturity tests.

(3) A determination of the effect of storage temperatures on the keeping quality of several varieties.

For this purpose a certain number of boxes of a variety were secured from the same orchard on the same day, and, as in all the experiments, care was taken to secure as nearly as possible the same type and grade of fruit. Part of each lot was stored immediately at a temperature of 31° to 32° F., and the remainder was also stored immediately at 35° to 36° F. During the seasons of 1912–13, 1913–14, and 1914–15 a limited number of boxes were stored in air-cooled storage houses at Hood River, Oreg., Payette, Idaho, and other points, while comparable lots of the same varieties were held at temperatures of 32° and 35° F. The system of inspection was similar to that followed for the maturity tests.

(4) A study of the keeping quality of different varieties grown and handled under ordinary commercial conditions and stored immediately at 31° to 32° F.

These experiments included nearly all varieties of importance or of promise as storage varieties grown in the three principal sections where work was done. A few varieties were included which, though not widely distributed, seem to possess very good keeping quality.

In addition to the above factors, tests were made of fruit grown on old and young trees, of poorly colored and well-colored fruit, of large and small fruit, of fruit from different soil types, of fruit grown under irrigation and without irrigation, and under cover crop and clean-culture conditions. Other experiments were conducted to determine the effect of dipping fruit in various fungicidal solutions or spraying it with a fungicide after picking as a means of controlling anthracnose decay and apple scab. The effect of water core and dry-rot on the keeping quality of the fruit has also been studied.

## TROUBLES AFFECTING APPLES IN STORAGE AND FACTORS IN THEIR CONTROL.

It must not be assumed that the conditions discussed under "Function of cold storage" entirely prevent storage troubles, for at no temperature and under no known condition is it possible to check entirely the physiological changes and ripening processes or the development of fungous decays without destroying the value of the fruit. Few varieties of apples will keep in perfect condition even in cold storage more than a few months, and varieties that will hold in good condition during a long storage season are decidedly valuable.

The troubles that affect northwestern apples in storage may be divided for this discussion into two main groups: (1) Those that affect only the external appearance of the fruit and are usually designated as skin blemishes and (2) those that injure the flesh of the fruit and are known as decays. Only those of considerable economic importance to the successful storage of northwestern apples will be described. For the sake of convenience in reference the most important factors governing the development and prevention of these various troubles in storage are briefly discussed here. The recommendations made are based on investigational results and also on commercial experience if such experience is available and considered reliable.

## SKIN BLEMISHES DEVELOPING IN STORAGE.

The most important skin blemishes are (1) scald, (2) Jonathan spot, (3) soft scald, (4) scab, and (5) bitter-pit; but there are others which are omitted because of their infrequent occurrence and relative economic unimportance in the Pacific Northwest. The importance of skin blemishes can not be overestimated, especially in the marketing of a crop such as the Pacific northwestern apple crop. It is safe to say that more than 25 per cent of all northwestern apples in cold storage are seriously affected by skin blemishes.

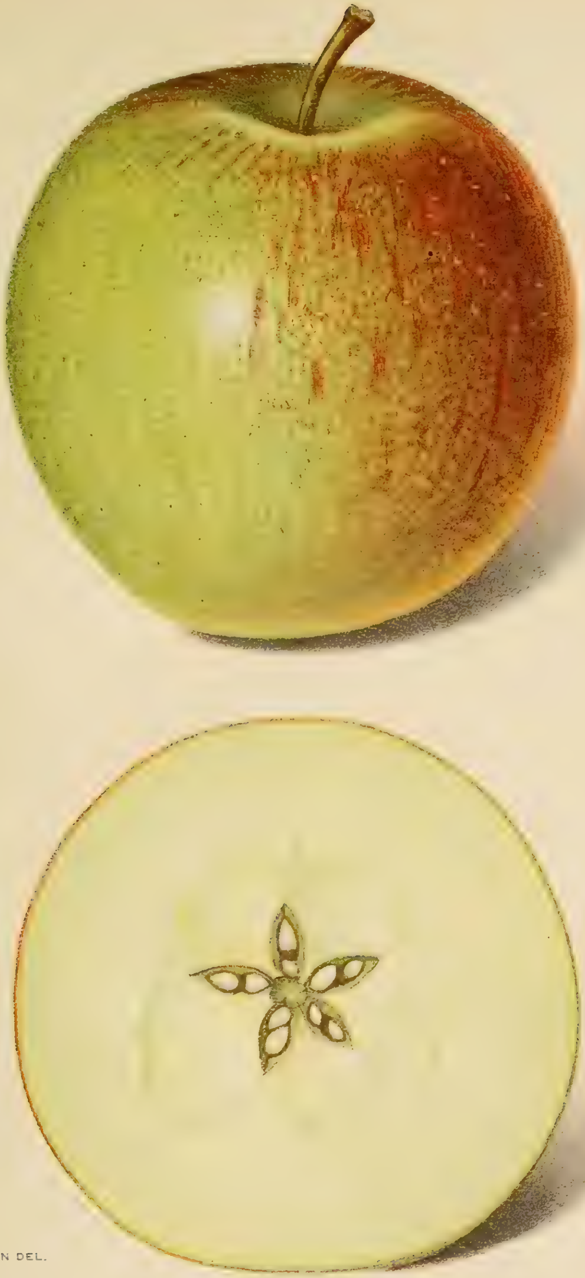
### FACTORS AFFECTING THE DEVELOPMENT OF SCALD IN STORAGE.

Scald is the most prevalent and most serious of the skin blemishes. It is a browning or blackening of the skin that does not extend into the flesh, but gives the fruit a scalded or baked appearance. Naturally this greatly lessens its commercial value. Plate II illustrates its appearance on Rome Beauty. Commercially scald can not be controlled absolutely, but through proper care in harvesting and storing it can be reduced greatly, and in this connection the following results of the experimental work are important:

(1) Striking differences are found in the susceptibility of varieties to scald. Probably no variety is absolutely immune. Rainier, Northern Spy, Jonathan, Hyde King, Esopus, and Missouri are comparatively so, while the Arkansas, Rome, Wagener, and others often develop an undue amount. Between these extremes come most of the more commonly grown varieties, and the susceptibility of these to scald varies greatly under the different conditions described below.

(2) There is a very appreciable decrease in the amount of scald on apples stored immediately as compared with those stored after a delay of two weeks. The amount of scald on the fruit stored immediately and that delayed two weeks before storage varies greatly with the weather conditions to which the delayed lots are subjected, and in cold weather there may be but little difference.

(3) Apples held at 32° F. scald slightly less than those stored at 35° F. or in common storage.

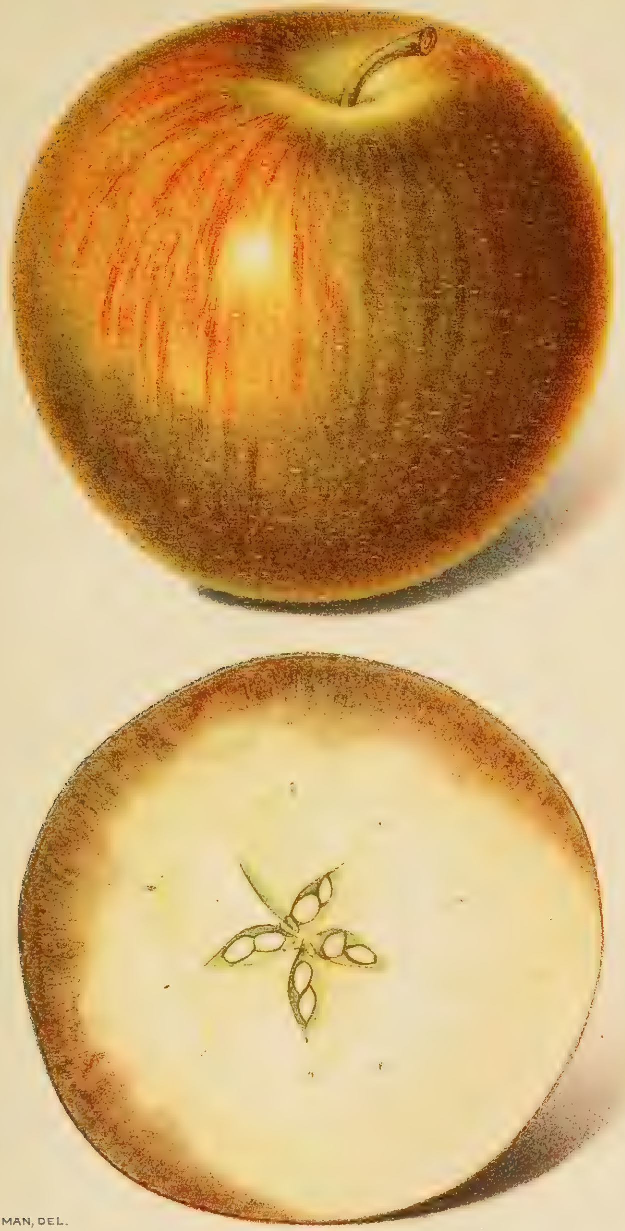

R. C. STEADMAN DEL.
A. HOEN & CO.

Rome Beauty Apples of Northwestern Production Picked Too Early for Holding Satisfactorily at Normal Storage Temperature of 32° F. for a Six-Months' Storage Period.

Fruits like the one in the upper figure, with a vivid leaf green area on the shaded side, are too immature for satisfactory storage, even though there is considerable color on the sunny side.

Cross section of a fruit at the same stage of maturity is shown in the lower illustration. The green color is apparent in the flesh.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)



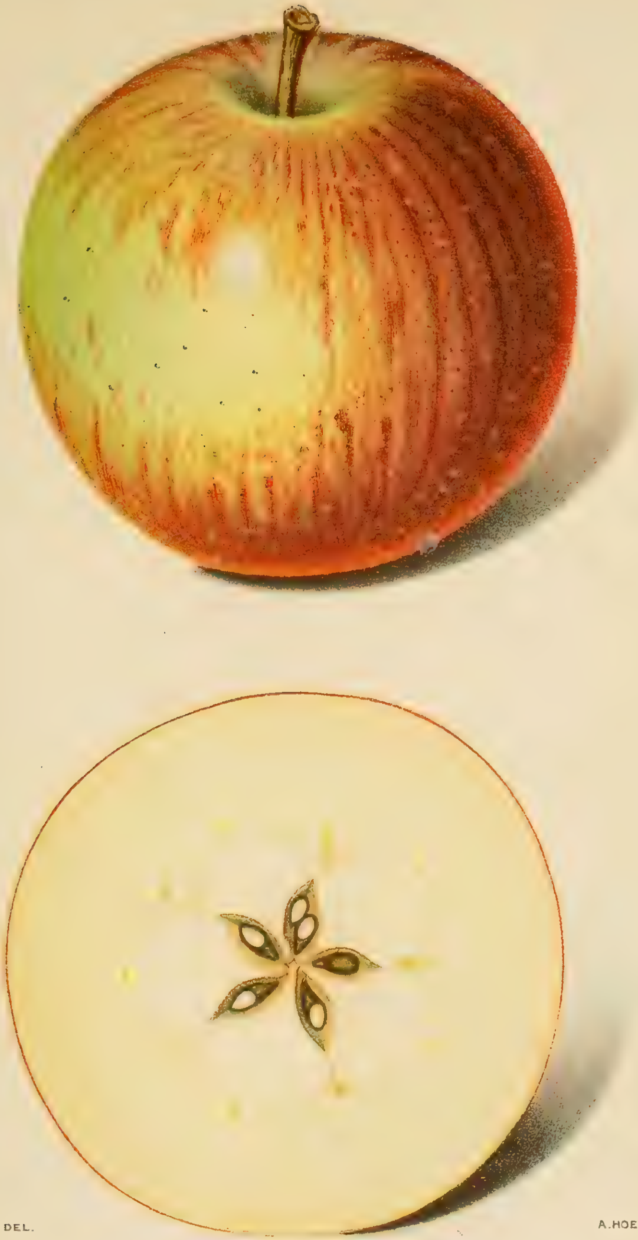
R.C. STEADMAN, DEL. A. HOEN & CO

RESULTS OF HOLDING ROME BEAUTY APPLES, AT THE STAGE OF MATURITY INDICATED IN PLATE I, AT 32° F. FOR SIX MONTHS.

External browning characteristic of fruits picked before the leaf green in the skin had disappeared and held in storage six months is illustrated by the upper figure.

The cross section of the same fruit shows that several layers of cells immediately below the skin, as well as the cells of the skin itself, have ceased to function and have become discolored.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)



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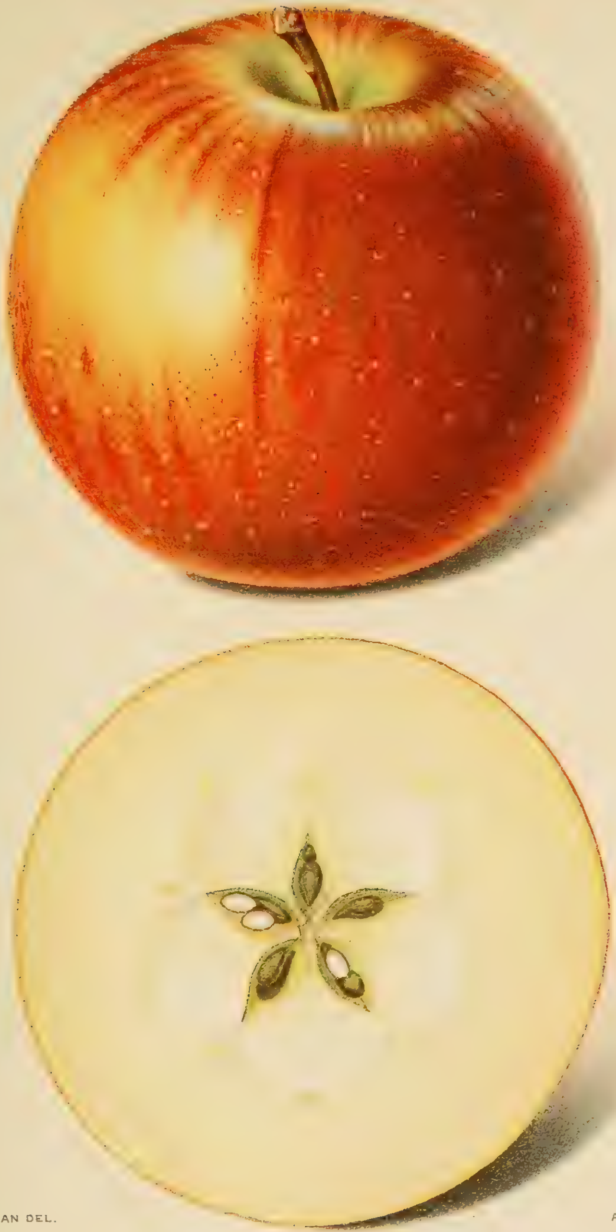
ROME BEAUTY APPLES OF NORTHWESTERN PRODUCTION HARVESTED AFTER THE LEAF GREEN HAD DISAPPEARED AND THE TRUE YELLOW OF THE NORMAL GROUND COLOR FOR THE VARIETY WAS DISCERNIBLE.

Absence of leaf green, the presence of white, and light yellow in its place—true signs of picking maturity in this variety—are shown in the upper figure.

Cross section of the same fruit from which the green tint in the skin as well as in the flesh has disappeared.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)



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ROME BEAUTY APPLES OF THE SAME STAGE OF MATURITY AS THOSE SHOWN IN PLATE III, AFTER HAVING BEEN HELD SIX MONTHS IN COLD STORAGE AT A TEMPERATURE OF 32° F.

No loss of color or discoloration, but the deepening of the yellow in the ground color due to progress of the ripening process, is shown in the upper figure.

The cross section of the fruit, shows no discoloration, but rather an increase in the yellow tint in the flesh, characteristic of the maturing of the variety.

(*From Yearbook U. S. Dept. of Agriculture, 1916.*)

(4) Of even more importance than the comparative susceptibility of varieties is the relation of time of picking to scald. The amount and severity of scald in immaturely picked apples in cold storage are often enormous. As the picking season advances and the fruit matures and colors, the damage decreases, until at near full maturity the scald is comparatively slight. Plates II and IV illustrate the effect of scald on Rome Beauty picked immaturely and at proper maturity after having been out of cold storage for almost three weeks. Plates I and III represent the general appearance of these same lots of apples at the time of picking. In the immaturely picked fruit very severe scald is followed by physiological decay. The intermediate lots have severe scald, but no physiological decay, while the apples picked at maturity show no scald whatever. Table I gives the average percentage of scald in six varieties of apples picked immaturely and at proper maturity upon their withdrawal from storage and also 10 days later. Plate II shows that the scald is confined principally to the uncolored portions on even the immature apples. Severe scald is seldom found on well-colored fruit.

Apples do not usually scald as badly in cold storage as in common or air-cooled storage houses. On withdrawal, however, scald may advance rapidly, and an apple that is perfect on withdrawal from cold storage may in a few days become worthless. Table I, except in the case of Rome Beauty and Arkansas Black, strongly emphasizes this point. It should be noted, however, that the apples picked at proper maturity are comparatively free from scald, both in storage and after withdrawal.

### FACTORS AFFECTING THE DEVELOPMENT OF JONATHAN SPOT IN STORAGE.

While affecting Jonathans principally, Jonathan spot is one of the most serious and important skin blemishes, as Jonathans are grown very extensively in all the Northwestern States and this variety is one of the leading commercial sorts in this region. This trouble appears as a small brown or black spot in the skin, usually one-sixteenth to one-quarter of an inch across and more or less rounded. In later stages it may enlarge somewhat and sink slightly. The flesh beneath is seldom injured more than a darkening of the layers of cells next to the skin. When severe, these spots are found scattered thickly over the whole surface of the apple, greatly reducing its market value.

(1) No other varieties are severely affected by Jonathan spot, although it develops occasionally on Esopus, Rome Beauty, and others.

(2) The spots on apples delayed two weeks or more before storage are usually considerably more numerous and severe than on those stored immediately after picking.

(3) While the difference is not as striking as between immediate and delayed storage, there is considerably less Jonathan spot on apples stored at 32° F. than on comparable lots stored at 35° F.

(4) While the data regarding the influence of time of picking on Jonathan spot are rather inconclusive, they indicate that it has little or no influence on its occurrence.

Jonathan spot, like scald, develops much more rapidly after withdrawal than in storage, though the increase is not as marked as in the case of scald. It is an interesting fact that some lots of Jonathans are severely affected by Jonathan spot, while others apparently identical in every other way are entirely free or nearly so.

### FACTORS AFFECTING THE DEVELOPMENT OF SOFT SCALD IN STORAGE.

Soft scald varies greatly in importance and severity in different years. None of the experiments so far has led to any definite conclusions. Jonathan, Blue Pearmain, and Wealthy seem to be particularly susceptible and are often rendered worthless in storage because of soft scald. Soft scald varies from small spots an eighth of an inch or less across to large areas that sometimes include the whole surface of the apple. The scalded area is light brown, becomes markedly sunken, is distinctly margined, and the flesh beneath turns brown and softens somewhat. In severe cases this condition may extend well into the flesh. The cause of soft scald is not definitely known, and there seems at present to be no way of preventing it.

As with the Jonathan spot, in one lot nearly every apple may be affected, while in others apparently no soft scald is found. Soft scald increases rapidly after withdrawal from cold storage, and fruit that is slightly affected when withdrawn may soon become worthless. There is usually more soft scald in apples delayed before storage than in apples stored immediately. On Jonathans the severity of soft scald increases rapidly after withdrawal from cold storage, and fruit severe on apples known to have been cooled to temperatures below 32° F. There are also indications that the trouble is related to box bruising or bruising resulting from very tight packing.

### FACTORS AFFECTING THE DEVELOPMENT OF SCAB IN STORAGE.

Scab is another serious skin blemish, differing from the forms previously mentioned in that it is a fungous disease and can be quite effectively controlled by proper spraying while the fruit is on the tree. This serious trouble often develops at a temperature of 32° F. on fruit apparently free from scab when stored. The orchard treatment of the crop must be such as to insure a product free from scab for storage, for it can not be controlled by spraying or by dipping in a fungicidal solution after the apples are picked. Preventive measures must be taken by the grower and can be taken by him alone. This again emphasizes the importance of good orchard sanitation, not only to maintain the vigor and health of the trees but also to preserve the quality and appearance of the fruit in storage. Because of its nature, scab is more conspicuous on yellow and green varieties than on red ones. There are few, if any, varieties that are entirely immune from the disease. As is the case with all fungous troubles affecting apples in storage, immediate storage and prompt cooling are of some value in reducing the injury, but the main reliance for its control must necessarily depend on proper spraying.[1]

### FACTORS AFFECTING THE DEVELOPMENT OF BITTER-PIT IN STORAGE.

Occasionally bitter-pit causes serious losses in storage and in the Pacific Northwest is frequently confused with fruit-spot and stigmonose. The fungous fruit-spot of the East is probably not present in the Pacific Northwest. Stigmonose, however, is common in this section and is very hard to distinguish from bitter-pit. The presence of a minute puncture in the skin over the affected area is sometimes the means of identifying stigmonose. The spots of the bitter-pit are usually visible on the surface as dark, slightly sunken areas one-eighth to one-third of an inch in diameter.

Many affected fruits are sorted out at packing time, but as they are hard to recognize and the pits often develop in storage, the trouble is not eliminated thereby. No effective methods of control have been suggested, as up to the present time the cause is not definitely known. It does not appear to be due to any organism, but is said to be caused by an unbalanced condition existing in the tree or parts of the tree that prevents the proper development of the fruit. Some varieties, such as Baldwin, Yellow Newtown, and others, appear to be particularly susceptible to the disease. It would not seem advisable to store apples for first-class trade from orchards where a high percentage of the fruit is thus affected. The disease mars the attractiveness of the fruit and renders it unfit for other than culinary use, but it does not appear seriously to affect its keeping qualities.

### TYPES OF DECAYS DEVELOPING IN STORAGE.

The decays affecting apples in cold storage may be divided into two general classes: (1) Physiological or natural death decay of fruit which has reached the end of its life; (2) fungous or bacterial decays or those caused by the growth of some organism in the tissue of the fruit. These again may be divided into two general classes: (1) Parasitic fungi, those that have the power of penetrating the sound unbroken skin of the fruit, and (2) saprophytic fungi, those that ordinarily do not penetrate the skin unless it is injured, broken, or in a weakened condition.

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[1] The various State experiment stations and the United States Department of Agriculture give concise directions for effective methods of scab control. Any failure properly to control scab under normal conditions is usually because the grower did not spray thoroughly or at the proper time.

### FACTORS AFFECTING THE DEVELOPMENT OF PHYSIOLOGICAL DECAY IN STORAGE.

Physiological or old-age decay is shown in Plates II and VII. All fruit, if not otherwise destroyed, eventually decays physiologically when it has passed through certain natural changes. It is essential to successful storage that these changes or ripening processes be retarded, as this is the fundamental principle upon which the cold storage of all fruits is based.

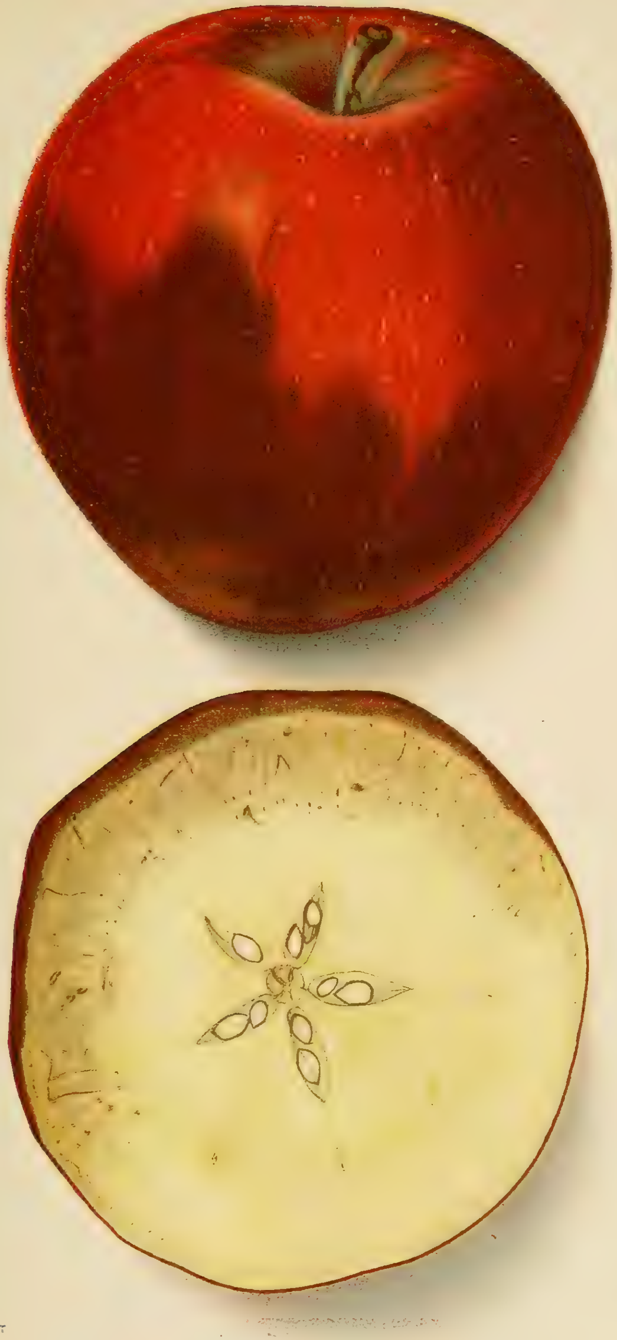
(1) *Soundness of fruit.*—One of the most important considerations in the control of physiological decay in storage is the selection of sound fruit of naturally long-keeping varieties. Such varieties as Rainier, Winesap, Arkansas Black, and Yellow Newton will, as is generally known, keep in good condition much longer than Grimes, Jonathan, and McIntosh.

(2) *Immediate storage compared with delayed storage.*—The promptness with which the fruit is stored and cooled after it is picked is the most important single factor in retarding physiological decay. After the apples are picked, a few days in the orchard or packing houses may greatly shorten their cold-storage life, especially if the weather is hot and the fruit is left in a warm place. Plates VI and VII show the condition of Jonathan apples as regards ripeness and maturity when stored immediately after picking and when delayed for two weeks before storage. There was no difference in treatment or handling except for the delay of two weeks in the grower's packing house before storing in the case of the apples shown in Plate VII. The life in cold storage of the immediately stored apples illustrated in Plate VI was at least a month longer than that of the delayed, Plate VII. There are few factors of greater importance than prompt cooling and storage in successfully prolonging the storage life of apples.

(3) *Storage at 32° and 35° F.*—In principle and results the storage of apples at a temperature of 35° F. is comparable with delayed storage, i. e., the slower the cooling and the higher the temperature at which the apples are held, the more rapidly will they ripen and death decay set in. Table IV gives the percentage of decay in comparable lots of apples stored at the two temperatures.

(4) *Apples picked while immature compared with those picked at maturity.*—Despite the fact that death decay is primarily the result of the completion of the life processes, it does not follow that apples picked previous to maturity will keep longer than fruit picked at maturity. Apples picked when immature, as previously noted, are usually very susceptible to scald. Severe scald is in turn very frequently followed by a peculiar type of physiological decay of the flesh directly beneath the scalded area. Plate II shows very clearly this type of physiological decay on a Rome Beauty.

PLATE V

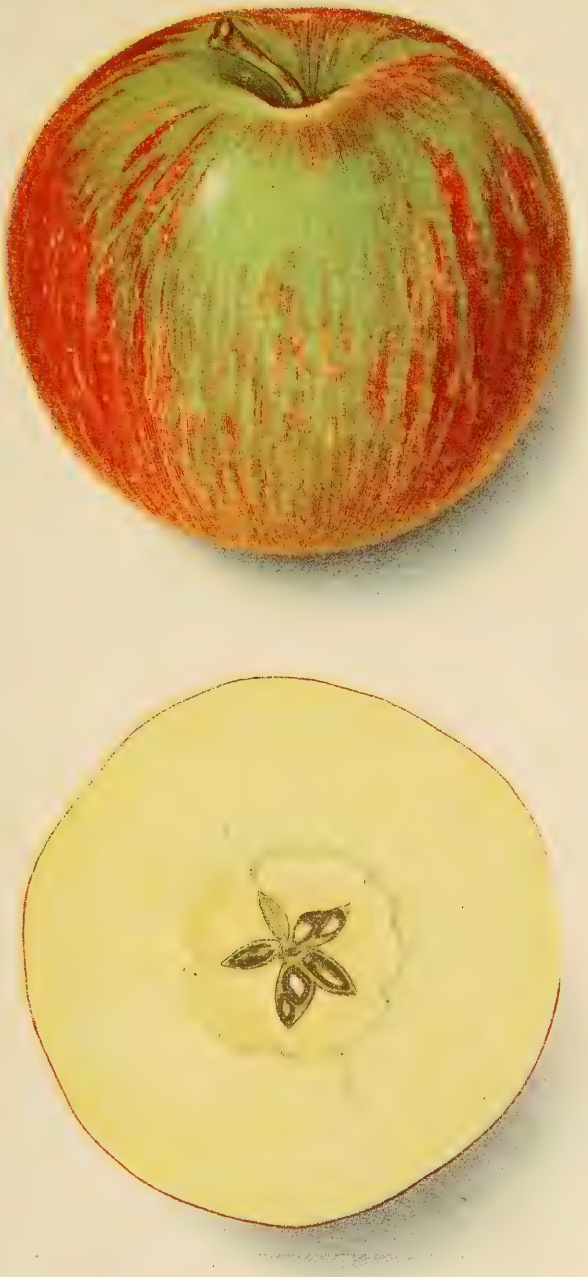


E. I. SCHUTT

A. HOEN & CO.

NORTHWESTERN-GROWN ESOPUS PICKED TOO LATE FOR HOLDING SATISFACTORILY AT NORMAL STORAGE TEMPERATURE OF 32° F. FOR A THREE AND ONE-HALF MONTHS' PERIOD.

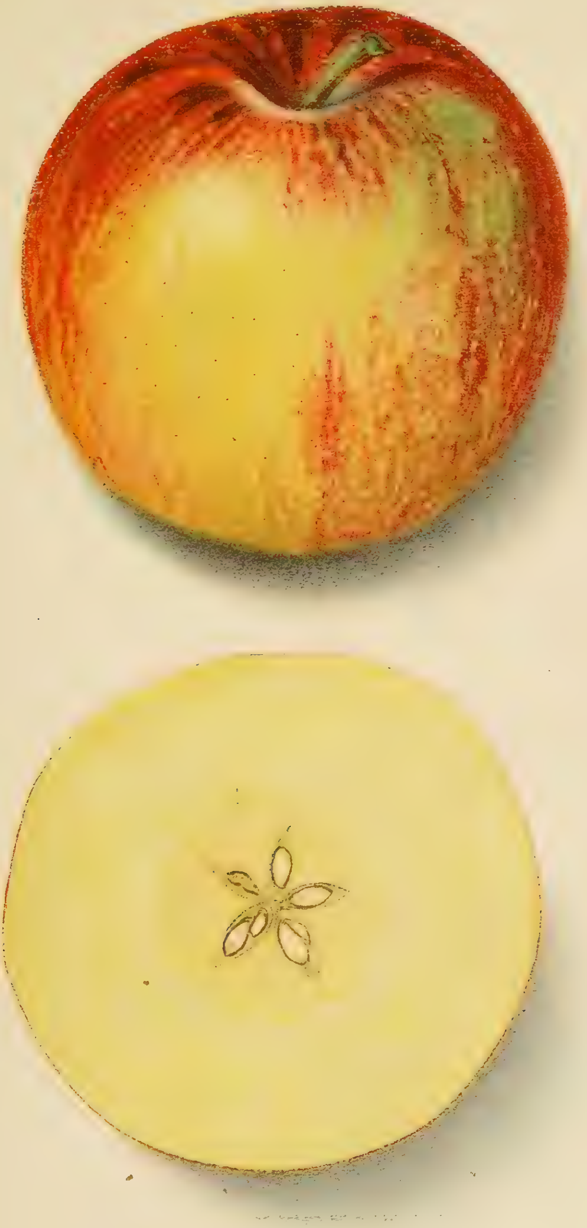
Picking at over-maturity is fully as serious as picking immaturely. Most serious storage losses in varieties like Esopus, King David, and Jonathan, are due to over-maturity at time of harvesting.



E. I. SCHUTT A. HOEN & CO.

NORTHWESTERN-GROWN JONATHANS IMMEDIATELY AFTER HARVESTING, WHEN WITHDRAWN FROM THREE MONTHS' STORAGE AT A TEMPERATURE OF 32° F.

Fruits like the above picked at the same time as the apple shown in Plate VII are still in prime condition and were held in storage for a month longer in perfect condition.



E. I. SCHUTT A. HOEN & CO.

NORTHWESTERN-GROWN JONATHANS DELAYED SEVERAL DAYS BEFORE BEING PLACED IN STORAGE WHEN WITHDRAWN FROM THREE MONTHS' STORAGE AT 32° F.

Fruits like the above, picked at the same time as the apple shown in Plate VI, are obviously too ripe even for immediate consumption, and entirely worthless for further storage. The delay of a few days prior to storage lessens oftentimes the length of time during which they can be held in storage by one or two months and seriously affects their flavor, quality, appearance, and market value.

(5) *Overmaturity.*—On the other hand, overmaturity is usually more disastrous than immaturity. It is practically the same as excessive delay, discussed under "Immediate versus delayed storage." The fruit has received all of its sustenance from the tree, and the ripening and life processes continue rapidly, especially in fruit exposed to the sun. Overmaturity is often responsible for the early decay of Esopus (Spitzenberg), King David, Jonathan, and others. During the season of 1914–15 more apples from various sections of the Northwest decayed early in the season from this cause than from any other. Table II gives a comparison of decay in Esopus picked at maturity and when overmature. The effect of overmaturity is well illustrated in Plate V.

(6) *Water-core.*—The cause of water-core is as yet unknown. Many theories are offered, but none seems satisfactory. Water-core is often largely responsible for early physiological decay. In storing such varieties as King David and Tompkins King it is advisable to be certain that little or no water-core is present, as water-cored fruit of these varieties usually decays early. In apples of firm flesh, such as Winesap and Yellow Newtown, in which the water-cored area is normally much smaller, the effect is not so severe. However, even in these varieties water-cored fruit should ordinarily not be held as long as that which is not affected. At best its storage is somewhat of a risk.

(7) *Bruising.*—It is at the bruised or weakened part of an apple that physiological decay first gets a start. Severe bruising not only injures the appearance but shortens the life of the fruit.

### FACTORS AFFECTING THE DEVELOPMENT OF PARASITIC FUNGI IN STORAGE.

Of the parasitic fungi, northwestern anthracnose (*Gloeosporium malicorticis* Cordley) is the only one at present of any great commercial importance. It may cause the decay of fruit in storage that is apparently sound at packing time, spreading rapidly from apple to apple and occasionally affecting all the fruit in a box.

Northwestern anthracnose begins as a minute tan-colored spot in the skin that spreads rapidly in warm, moist conditions over a large area and extends into the flesh. Usually several spots appear on each affected apple. They are round or oval and often grow together as they increase in size. Both skin and flesh are light brown and are nearly odorless and tasteless. Occasionally small pustules may be seen on the surface. At a late stage white spore masses on the surface are not uncommon and the skin may break. Immediate storage is of some value in delaying the period of development. Time of picking, color, and careful handling play little or no part in control. Neither does dipping the fruit in a copper-sulphate solution before packing prevent attack. The decay spreads very rapidly after withdrawal from storage. The control of northwestern anthracnose must necessarily lie in proper orchard sanitation practices.[1]

### FACTORS AFFECTING THE DEVELOPMENT OF SAPROPHYTIC FUNGI IN STORAGE.

Blue mold stands out above all other fungi of this class in importance. Although it is the most common fungous enemy of northwestern apples in storage, it is fortunately one that can be controlled almost entirely. In the field and in storage this fungus gains entrance through any broken or weakened portion of the skin. It is easily recognized by its distinctive odor, and in its later stages by an abundance of small tufts and masses of green spores on the infected areas.

(1) The resistance of varieties to blue mold bears a direct relation to toughness of skin and length of stem. Varieties with tender skins and long stems with which other apples in the box may be punctured are likely to be most susceptible to blue mold.

(2) The higher the temperature, the faster the development of the fungus. For this reason, immediate storage is better than delayed, and 32° F. is better than 35° F.

(3) Because of the weakening effect of severe scald, immature or poorly colored fruit is occasionally more susceptible to blue mold than well-colored apples.

(4) Careful handling is the fundamental factor in the control of blue mold. It is seldom that an infection can not be traced to some injury of the apple that could have been prevented.

## RESULTS OF THE EXPERIMENTS.

The importance of good orchard sanitation in preventing the development of storage rots and skin blemishes has already been pointed out. As a matter of fact, the grower's responsibility goes back even farther. He more than any other single individual influences the keeping quality of his fruit in storage, since by his orchard practices he is directly responsible for its quality, vitality, and freedom from disease. Only gross negligence on the part of the shipper or warehouseman can nullify the effect of good cultural and sanitary orchard practices. On the other hand, if fruit is poorly grown or is diseased the utmost care on the part of the warehouseman can not prevent the premature development of storage troubles.

Assuming, then, that one has well-grown and well-developed apples, free from disease, the important steps in the successful storage of this fruit are as follows:

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[1] Information regarding pruning and spraying practices for the control of northwestern anthracnose can be obtained from the experiment stations in the various States.

(1) Picking at a proper maturity.
(2) Care in all handling operations.
(3) Prompt storage.
(4) A proper storage temperature.

## MATURITY AT THE TIME OF PICKING.

Table I gives the average percentage of serious storage troubles found in Rome Beauty, Winesap, Yellow Newtown, Stayman Winesap, Ortley, and Arkansas Black when picked at and somewhat before full maturity. These include "bad scald," the term used to designate scald that is serious enough to detract from the commercial value of the fruit, and physiological and fungous decays. Other storage troubles are noted as they appear in the various lots. The results given for Yellow Newtown and Rome Beauty are an average of the data obtained during the four seasons the work has been carried on. The Winesap results are an average of three seasons' experiments, 1912–13, 1913–14, and 1914–15. The Stayman Winesap and Ortley data cover but two seasons, while the data for Arkansas Black are for one year, but include several lots.

No definite statement can be made regarding the commercial picking dates of a variety. Yellow Newtown, Rome Beauty, and Winesap may usually be harvested any time between the latter part of September and first of November, depending upon seasonal conditions and the degree of maturity desired. Great variation in the time at which apples mature is also caused by the age of the trees, the soil, cultural conditions, elevation, and the site of the orchard. In general, the immature pickings of these varieties were made during the last two weeks of September and the mature pickings from October 2 to October 20.

The first three sections of Table I and Plates I and II show the injurious effect of immature picking clearly enough to require little discussion. In Rome Beauty (Table I) at the third withdrawal from storage, March 31 to April 2, the immature fruit developed more than 48 times as much bad scald in storage as the mature fruit. Even at the last withdrawal, May 4 to 11, there was 17 times as much bad scald in the early as in the mature picking. These figures, it must be remembered, are not the results of a single experiment, but the average of several experiments covering a period of four years. The results with Winesap (Table I) are equally striking. It is reliably estimated that several thousand dollars are lost to the industry each year by premature pickings of these two varieties alone. As the first pickings were made no earlier than a considerable portion of the same varieties are picked commercially, the necessity for strict attention to this point is plainly evident.

TABLE I.—*Comparison of mature and immature apples with regard to the percentage of bad scald and decay at withdrawal from storage and with regard also to the total percentage after a holding period of 10 days under market conditions, the time in storage at first withdrawal being three to three and one-half months.*

ROME BEAUTY (FOUR-YEAR AVERAGE).

| Condition. | First withdrawal, Jan. 8 to 12. | | Second withdrawal, Feb. 16 to 19. | | Third withdrawal, Mar. 31 to Apr. 2. | | Fourth withdrawal, May 4 to 11. | |
|---|---|---|---|---|---|---|---|---|
| | Mature. | Immature. | Mature. | Immature. | Mature. | Immature. | Mature. | Immature. |
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0 | 0 | 20.5 | 1.0 | 48.9 | 3.5 | 58.9 |
| 10 days later..... | 1.7 | 49.9 | 5.4 | 70.5 | 10.4 | 81.5 | 17.8 | 81.6 |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | .1 | 0 | 0 | 0 | .2 | .1 | .4 |
| 10 days later .... | .2 | .6 | .2 | 0 | 1.6 | 9.8 | 2.7 | 18.0 |

WINESAP (THREE-YEAR AVERAGE).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0.1 | 0 | 7.6 | 0 | 15.5 | 0.6 | 15.5 |
| 10 days later..... | 0 | 9.6 | .2 | 13.9 | 3.3 | 25.7 | 11.3 | 33.5 |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | 0 | .3 | .3 | .5 | .3 | .5 | .6 |
| 10 days later..... | .1 | .1 | .3 | .3 | .8 | .5 | .7 | .7 |

YELLOW NEWTOWN (FOUR-YEAR AVERAGE).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0 | 0 | 0 | 0 | 0.5 | 2.1 | 0 |
| 10 days later..... | 0 | 1.8 | 2.1 | 1.3 | 1.5 | 1.0 | 14.8 | 19.8 |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 days later..... | 0 | 0 | 0 | .2 | 0 | 0 | 2.0 | 2.6 |

STAYMAN WINESAP (TWO-YEAR AVERAGE).

| Condition. | First withdrawal, Jan. 14 to 18. | | Second withdrawal, Feb. 25 to 28. | | Third withdrawal, Mar. 31 to Apr. 2. | | Fourth withdrawal, May 7 to 11. | |
|---|---|---|---|---|---|---|---|---|
| | Mature. | Immature. | Mature. | Immature. | Mature. | Immature. | Mature. | Immature. |
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 1.1 | 8.9 | 84.3 | 39.4 | 86.1 | 41.0 | 91.8 |
| 10 days later..... | 11.4 | 87.5 | 36.6 | 92.8 | 51.6 | 90.2 | 65.1 | 92.6 |

ORTLEY (TWO-YEAR AVERAGE).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0 | 4.0 | 6.6 | 9.9 | 30.4 | .......... | .......... |
| 10 days later..... | 3.1 | 3.7 | 17.4 | 30.0 | 40.1 | 48.1 | .......... | .......... |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | 0 | 2.0 | 1.1 | 7.0 | 7.0 | .......... | .......... |
| 10 days later..... | 1.1 | 0 | 3.5 | 4.0 | 20.7 | 25.5 | .......... | .......... |

ARKANSAS BLACK (RESULTS OF ONE YEAR WITH LOTS FROM SEVERAL SECTIONS).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.2 |
| 10 days later..... | 0 | 0 | 0 | 6.0 | 0 | 7.7 | 1.3 | 52.8 |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | 0 | 0 | 0 | 0 | 0 | .6 | 0 |
| 10 days later..... | 0 | 0 | 0 | 0 | 0 | .6 | 4.2 | 10.8 |

NOTE.—Slight inconsistencies such as those noted above are not uncommon where the results of only one or two years' work are available. It is because of this fact that except where substantiated by other evidence it is not safe to generalize on only one or two years' data.

In Rome Beauty, Winesap, and Yellow Newtown scald causes more serious injury than decay. It has been found that all varieties susceptible to scald are attacked much more quickly and seriously when picked prematurely than when picked at full maturity, as shown in Plates II and IV. The most practical and efficacious preventive of this trouble, therefore, is picking the fruit at proper maturity. No other factor has such an important bearing on the amount of scald which develops in storage. The general appearance of scald on Rome Beauty is well illustrated in Plate II. It is probable that the cells which make up the skin of the immature fruit are undeveloped and weak, and therefore break down quickly in storage. In this connection it is important to note that physiological decay, such as is shown in Plate II, often follows severe scald. In the case of red varieties, allowing the fruit to remain on the tree until proper maturity is reached permits the green area to become partially or completely colored (Pl. III) and consequently practically immune from scald. It also allows the whole surface of one naturally green or yellow in color to become mature enough to resist the trouble.

As far as physiological and fungous decays are concerned, the differences shown in the table are not so striking. Very serious scald, however, finally weakens the skin of the fruit so that complete physiological decay results or a point of entrance is offered to decay fungi. This explains the very serious decay in the immature Rome Beauty at the third and fourth withdrawals. It will be observed that very little of this decay developed at 32° F., but after withdrawal to the warmer outside temperatures the immature fruit, weakened by bad scald, went down very rapidly, while a comparatively small amount of decay developed in the fruit which was mature when picked.

Winesap, usually considered a longer keeping variety than Rome Beauty, was apparently not seriously weakened by scald, as very little decay developed either in storage or after withdrawal. Yellow Newtown (Table I) shows considerably more decay in the immature lots than in the mature at the last withdrawal, though the difference in the percentage of scald is much less pronounced than in the first two varieties. These differences, however, were greater than the figures indicated. The individual apples in the immature lots were, as a rule, more seriously affected than those in the mature lots, and consequently more weakened and more susceptible to decay.

## WHEN IS AN APPLE AT PROPER MATURITY?

Regarding the stage of maturity at which apples should be picked it is difficult to give directions which will apply to all conditions and seasons. Proper maturity certainly does not mean eating ripe, as in nearly every case an eating-ripe apple is overmature for storage. The individual growers should study their own fruit and their own conditions and whenever possible should make experiments to determine the stage of maturity at which the varieties they grow hold best in storage. The color of the seeds gives some indication, yet in spite of many opinions to the contrary it is an unreliable index to the maturity of the fruit. Many factors may cause the color of the seeds to vary without affecting materially the time at which the fruit reaches full maturity. The blush or red color of the apple taken by itself also is unreliable. Both of these factors should be taken into consideration, however. Perhaps the most reliable single indication is the "ground" color of the fruit; that is, the color which underlies the red color or blush. The "ground" color, which is green when the fruit is immature, begins to whiten or yellow slightly as it approaches full maturity. Plates I and III illustrate very well immature and mature Rome Beauty apples at time of picking. As a rule, in a mature apple the green color should be largely replaced by a white or light-yellow color. A dark yellow, on the other hand, usually indicates overmaturity. Allowances, of course, should be made for the natural color of the variety, the amount of exposure to sunlight, etc. Experience will enable a grower to give the proper weight to each one of these factors and properly to coordinate them.

## EFFECT OF OVERMATURITY.

It may be stated that certain varieties, of which Rome Beauty and Winesap are examples, are, as a rule, picked too early to keep in the best condition in storage. Some other varieties, however, such as Jonathan and Esopus (Spitzenberg), sometimes are left on the trees later than is advisable. It should be understood clearly that maturity does not mean overmaturity, and that overmaturity may cause losses as serious, or even more serious, than those due to immaturity. As might be expected, the storage troubles resulting in this case are physiological and fungous decays. An apple allowed to remain on the tree until overripe is much farther advanced in its life processes than it is if picked at proper maturity and breaks down just so much faster in storage. The final breakdown may be due either to premature physiological decay or to a fungous rot which the weakened fruit can not resist. The complete destruction of the fruit follows in either case. Trouble of the kind in Esopus (Spitzenberg) is shown in Table II, the last picking of which was made when the fruit was overmature. Plate V illustrates the condition after removal from storage of Esopus apples picked when overmature.

TABLE II.—*Comparison of mature and overmature Esopus (Spitzenberg) apples with regard to the percentage of physiological and fungous decay at withdrawal from storage and with regard also to the percentage of decay after a 10-day holding period under market conditions, one experiment, 1913–14.*

[The first pick was made September 25 and stored September 26, 1913; the second pick was made October 10 and stored October 11, 1913.]

| Condition. | First withdrawal, Jan. 12, 1914. | | Second withdrawal, Feb. 19, 1914. | | Third withdrawal, Apr. 1, 1914. | | Fourth withdrawal, May 4, 1914. | |
|---|---|---|---|---|---|---|---|---|
| | First pick. | Second pick. | First pick. | Second pick. | First pick. | Second pick. | First pick. | Second pick. |
| Decay: | | | | | | | | |
| At withdrawal... | 0.0 | 2.3 | 0.0 | 9.1 | 1.3 | 4.0 | 2.7 | 14.0 |
| 10 days later...... | 1.3 | 2.3 | 1.3 | 25.0 | 2.7 | 26.0 | 6.7 | 36.0 |

At the second withdrawal, February 19, which is somewhat later than the usual commercial storage limit for this variety, the first picking was free from decay or other storage troubles, while the later picking had developed 9.1 per cent decay. After being held outside for 10 days, a period approximating the usual length of time from storage to consumption, the decay in the late picking increased to 25 per cent. The first picking developed only 1.3 per cent in the same period. In other words, one lot was in prime market condition and the other in very poor condition. The later inspections are well past the commercial limit for the variety, and the decay is correspondingly heavier, though still consistently less in the first picking. The fact that less decay was found in the second picking at the third withdrawal than at the second withdrawal over a month before is an inconsistency which sometimes arises where only one series of observations has been made. Inconsistencies of this nature are largely eliminated when the results of several experiments are averaged.

Although decidedly inferior in keeping quality, the second picking was strikingly superior in color. This factor, however, did not add to the value of the fruit sufficiently to counterbalance the difference in amount of decay. Possibly a picking made between the two would be superior to either and might have possessed the keeping quality of the first picking with a large portion of the color of the second.

## CAREFUL HANDLING.

No special investigations have been conducted with the apples of the Northwest relative to the effect of careful handling in lessening injuries which render the fruit liable to attacks of blue mold and other saprophytic fungi. Extensive experiments by the Bureau of Plant Industry, however, have demonstrated conclusively that care in all handling operations is of primary importance in insuring sound fruit, whether in storage or in transit. The results of these investigations, which have covered many classes of fruit, have been published as bulletins of the Department of Agriculture,[1] and it is unnecessary to discuss this subject in any detail here.

The fact that blue mold causes serious storage decay in apples, especially those that have been carelessly and roughly handled, is of special interest to the apple growers of the Northwest. As has been previously stated, the fungus causing this trouble can not affect uninjured, healthy fruit, and decay due to this cause can be largely prevented by reasonable care in the harvesting and handling operations. Common sources of injury under commercial handling methods are very numerous. Finger-nail scratches by the pickers or packers, allowing sand and gravel to accumulate in the bottom of the boxes or nails and splinters to project from the bottom and sides, dropping the fruit carelessly into the picking boxes, careless stacking of the filled picking boxes in the field or on the wagon, and rough handling in loading the fruit and hauling it over rough roads on springless wagons are all sources of injury. In the packing house or shed the fruit is frequently dumped roughly into the packing bins and may be injured further by an improperly constructed or adjusted mechanical sizer. Injuries caused by stem punctures and cover bruises, which may be due to improper packing, or carelessness on the part of the pressman, are of very frequent occurrence. Many of the injuries caused in this way may be very small. None of them, however, is insignificant. A microscopic break in the skin of an apple is sufficiently large to afford entrance to the decay fungi, and bruises which are not noticeable when the fruit is packed may cause premature physiological decay in storage.

Careful handling includes careful grading. All poorly developed, imperfect, and injured fruit should be eliminated from the storage lots.

## IMMEDIATE VERSUS DELAYED STORAGE.

When an apple is removed from the tree, growth ceases, but the life processes which result in ripening continue more or less rapidly, the rapidity depending on the temperature at which the fruit is held. Under high temperatures ripening goes on very rapidly and the fruit approaches the end of its natural life much more quickly than when these processes are retarded by low temperatures.

Delay before storage usually involves the exposure of the fruit for a longer or shorter period to a temperature decidedly higher than that of a cold-storage room. The rapidity of ripening is therefore much greater, and the end of its life, even if it is subsequently placed in cold storage, comes just so much sooner than it otherwise would. It may be expected then that fruit treated in this way will show a much higher percentage of physiological and fungous decay in storage than that stored immediately after picking and that it will be more seriously affected by skin blemishes.

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[1] Bulletins of the United States Department of Agriculture No. 63, Factors Governing the Successful Shipment of Oranges from Florida; No. 274, Factors Governing the Successful Shipment of Red Raspberries from the Puyallup Valley; No. 331, The Handling and Shipping of Fresh Cherries and Prunes from the Willamette Valley.

In all the experiments of this nature, the delayed lots were held two weeks in growers' or shippers' warehouses at a temperature only slightly lower than that of the outside air. In every other respect each delayed lot was comparable with the corresponding "immediate." The data given do not fully represent the differences between the lots. The immediately stored fruit was always brighter, less yellow, and usually firmer than the delayed. Plates VI and VII illustrate the differences in ripeness upon withdrawal of Jonathans stored immediately and those delayed two weeks. The immediately stored lots, from which the apples in the illustrations were taken, held in storage in good condition one month longer than the comparable delayed apples. Toward the end of the storage period the delayed fruit frequently showed considerable shriveling, while the shriveling in the same fruit stored immediately was slight or entirely absent. Table III shows that there was consistently more bad scald and decay in the fruit delayed for two weeks than in that stored immediately. Data for the most important varieties represented in these experiments are given in the table. This fruit usually was picked at the height of the commercial season for the variety. Definite dates would only be misleading, because, as has been said, these vary greatly with conditions.

The effect of delayed storage on the keeping quality of the fruit varies greatly with different varieties and with climatic and seasonal conditions. If warm weather and high humidity are experienced during the delay period, the ripening of the fruit goes on very rapidly, and, in addition, conditions are then most favorable for the growth and development of fungi causing decay and skin blemishes. On the contrary, if the weather is cool and dry, ripening is comparatively slow and the development of fungous troubles is retarded. Under these conditions, the delay may be only slightly injurious. The table given shows the results with fruit held under varying conditions of temperature and humidity, and the data are the averages of the differences that may be expected to develop between immediately stored and delayed fruit. They do not show the maximum amount of storage troubles that will result from delay during warm and humid weather.

TABLE III.—*Comparison of immediate and delayed storage of apples with regard to the percentage of bad scald and decay at withdrawal from storage and with regard also to the total percentage after a holding period of 10 days under market conditions, the time in storage at first withdrawal being three to three and one-half months.*

YELLOW NEWTOWN (THREE-YEAR AVERAGE).

| Condition. | First withdrawal, Jan. 8 to 13. | | Second withdrawal, Feb. 19 to 21. | | Third withdrawal, Mar. 27 to Apr. 3. | | Fourth withdrawal, May 6 to 13. | |
|---|---|---|---|---|---|---|---|---|
| | Immediate. | Delayed. | Immediate. | Delayed. | Immediate. | Delayed. | Immediate. | Delayed. |
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 1.2 | 1.8 | 6.4 | 6.3 | 23.5 | 11.0 | 30.2 |
| 10 days later..... | 2.6 | 19.5 | 9.8 | 33.3 | 27.6 | 43.6 | 28.2 | 56.5 |
| Decay: | | | | | | | | |
| At withdrawal... | .4 | 0 | .3 | 0 | .9 | .9 | .8 | 1.9 |
| 10 days later..... | .6 | .6 | .8 | .4 | 2.9 | 5.4 | 5.2 | 14.4 |
| WINESAP (FOUR-YEAR AVERAGE). | | | | | | | | |
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0 | 0 | 0.2 | 1.2 | 2.3 | 0.4 | 1.7 |
| 10 days later..... | 0 | 1.3 | .8 | .9 | 3.8 | 6.4 | 7.3 | 8.8 |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | .2 | 0 | 0 | .4 | 1.0 | .1 | .4 |
| 10 days later..... | .4 | .4 | 0 | 0 | .7 | 1.6 | .8 | 1.3 |

ROME BEAUTY (FOUR-YEAR AVERAGE).

| Condition. | First withdrawal, Jan. 9 to 12. | | Second withdrawal, Feb. 16 to 29. | | Third withdrawal, Mar. 27 to Apr. 2. | | Fourth withdrawal, May 5 to 14. | |
|---|---|---|---|---|---|---|---|---|
| | Immediate. | Delayed. | Immediate. | Delayed. | Immediate. | Delayed. | Immediate. | Delayed. |
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0 | 1.8 | 3.0 | 11.3 | 21.9 | 22.2 | 27.9 |
| 10 days later..... | 12.6 | 18.3 | 23.7 | 40.0 | 28.4 | 49.6 | 42.5 | 67.1 |
| Decay: | | | | | | | | |
| At withdrawal... | .3 | .6 | .5 | 2.6 | 1.0 | 4.4 | 1.7 | 3.7 |
| 10 days later..... | 1.2 | 2.8 | 1.2 | 5.8 | 3.3 | 13.4 | 13.6 | 21.5 |
| ESOPUS (FOUR-YEAR AVERAGE). | | | | | | | | |
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 0 | 0 | 0 | 0.4 | 0 | 0 | 0 |
| 10 days later..... | 0 | 0 | 0 | 0 | 1.7 | .5 | 1.6 | 2.8 |
| Decay: | | | | | | | | |
| At withdrawal... | .1 | 2.4 | 2.6 | 4.3 | 6.4 | 9.2 | 8.9 | 12.1 |
| 10 days later..... | 1.4 | 6.5 | 6.0 | 10.0 | 11.3 | 22.1 | 23.4 | 28.4 |
| JONATHAN (FOUR-YEAR AVERAGE). | | | | | | | | |
| Bad scald: | | | | | | | | |
| At withdrawal... | 0 | 4.0 | 0.1 | 6.7 | 8.5 | 21.5 | 17.9 | 33.8 |
| 10 days later..... | 1.0 | 7.3 | 8.4 | 20.0 | 14.7 | 35.8 | 27.0 | 46.4 |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | .3 | 4.6 | 10.3 | 6.8 | 13.1 | 7.8 | 13.0 |
| 10 days later..... | 1.2 | 1.2 | 10.1 | 12.7 | 12.2 | 17.5 | 12.0 | 17.0 |

In the Pacific Northwest, as in all apple sections of the United States, the fruit after picking is held frequently two weeks or longer in an open warehouse, or even in the orchard, before it is shipped or stored. The delay period selected for the experimental lots is not excessively long, therefore, and is entirely representative of delay under commercial conditions. Much of the delay of commercially handled fruit is unavoidable, but a great deal of it could be eliminated by a reasonable modification of orchard and packing-house methods. When it is impossible for a grower to store or ship his fruit promptly after it is picked, he should hold it at the lowest temperature available. A common storage room in which the fruit temperatures may be reduced by the cooler night air, and which is sufficiently insulated to maintain this lower temperature during the day, is a valuable adjunct to any orchard and is becoming increasingly necessary in handling the apple crop. In brief, the grower should keep clearly in mind the fact that the higher the temperature at which his fruit is held after it is picked, the more rapid will be its ripening and deterioration.

With the longer keeping varieties, such as Winesap, the effect of a delay prior to storage is not as marked as with the earlier, shorter lived ones, and may not be noticeable during the first part of the storage season. As the fruit advances in its storage life, the differences between immediately stored and delayed lots become greater, and the injurious effect of the delay becomes apparent. With the Jonathan, on the other hand, consistent and striking differences usually are noticeable before the fruit has been in storage two months. The excessive amount of Jonathan spot, or "arsenic spot," following delayed storage, is especially pronounced in this variety, and it is very evident that prompt storage is an important factor in retarding the development of this trouble.

## THE EFFECT OF STORAGE TEMPERATURES.

For successful long storage northwestern-grown apples should be held at the lowest temperature possible without danger of freezing. A temperature between 31° and 32° F. is accepted generally as the most favorable for successful storage. Although the exact freezing point of apples has not been definitely determined and may vary with different varieties and conditions of growth, etc., it is known to be 2 or 3 degrees lower than this. Thirty-two degrees F. is the freezing point of distilled water, and a somewhat lower temperature is required to freeze a concentrated fruit juice. Unless a good continuous air circulation is assured in the storage room, however, 31° F. should be considered the lowest limit at which the temperature can be held with safety. The danger from pockets of colder air at the floor, the refrigeration pipes, or cold-air ducts renders it inadvisable to allow the temperature to drop lower unless a thorough and constant air circulation is assured.

In all the experiments the fruit held at 32° F. was in better condition and could be held through a longer storage period than that stored at a temperature ranging from 35° to 36° F. The practical effect of this higher temperature was the same as that of delay before storage. The life activities of the fruit stored at 35° F. advanced with greater rapidity than at 32° F. Consequently at all withdrawals fruit stored at 35° F. was found to be duller, yellower, and riper than the fruit held at 32° F. This was especially true at the later withdrawals. In addition, a higher percentage of scald and storage decays developed at 35° F.

Table IV shows the percentages of decay found in three of the varieties represented in these experiments. Each section of the table gives an average of all experiments conducted during three shipping seasons, 1912–13, 1913–14, and 1914–15. All the fruit was picked at the height of the commercial picking season for each variety, and the lots held at 32° F., as well as those at 35° F., were stored as soon as possible after picking, generally not more than two days later.

TABLE IV.—*Comparison of apples stored at 32° and 35° F. with regard to the percentage of decay at withdrawal from storage and with regard also to the total percentage after holding 10 days under market conditions, 3-year average, the time in storage at first withdrawal being three to three and one-half months.*

ESOPUS (SPITZENBERG).

| Condition. | First withdrawal, Jan. 7 to 13. | | Second withdrawal, Feb. 17 to 21. | | Third withdrawal, Mar. 31 to Apr. 3. | | Fourth withdrawal, May 5. | |
|---|---|---|---|---|---|---|---|---|
| | 32° | 35° | 32° | 35° | 32° | 35° | 32° | 35° |
| Decay: | | | | | | | | |
| At withdrawal... | 0 | 0.7 | 0.6 | 4.8 | 10.1 | 13.9 | 12.4 | 15.1 |
| Ten days later... | .7 | 8.4 | 2.9 | 11.9 | 12.4 | 17.4 | 21.4 | 26.4 |

ROME BEAUTY.

| Condition. | First withdrawal, Jan. 12 to 16. | | Second withdrawal, Feb. 20 to 21. | | Third withdrawal, Apr. 2. | | Fourth withdrawal, May 5. | |
|---|---|---|---|---|---|---|---|---|
| | 32° | 35° | 32° | 35° | 32° | 35° | 32° | 35° |
| Decay: | | | | | | | | |
| At withdrawal... | 0.6 | 0.7 | 1.6 | 2.3 | 0.3 | 1.3 | 2.4 | 4.8 |
| Ten days later... | 1.8 | 1.3 | 2.0 | 2.3 | 2.3 | 4.4 | 10.2 | 13.2 |

WINESAP.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Decay: | | | | | | | | |
| At withdrawal... | 0.1 | 0.2 | 0 | 0.2 | 0.3 | 1.2 | 0.5 | 0.7 |
| Ten days later... | .3 | .4 | 0 | .3 | .8 | 3.1 | 1.1 | 3.7 |

It will be noted that early in the storage season there is little difference in the amount of decay which develops in Winesap and

Rome Beauty stored at 32° and 35° F. Noticeable differences in appearance and texture were apparent in nearly all lots at this time, however. At the third and fourth withdrawals of these varieties the fruit stored at 35° showed considerably more decay than that stored at 32° F. In other words, fairly good keeping varieties may be held for some time at a temperature of 35° F. with practically as good results as far as loss from decay is concerned as if the fruit had been held at a lower temperature. As these varieties approach the end of their storage periods, however, the effect of the higher temperature is manifest, and the failure properly to retard the life activities of the fruit results in its premature death and decay. This is especially noticeable during the holding period after the fruit has been withdrawn from storage. The apples stored at 32° F. had enough reserve vitality to hold in good condition during this period, but the more advanced 35° F. fruit went down with comparative rapidity.

In Esopus (Spitzenberg) striking results are noted at the first two withdrawals and inspections. As the storage life of this variety is naturally shorter than that of Winesap and Rome Beauty, results of this kind are to be expected. Storage at 35° F. has materially shortened the holding period of the lots so treated, and this influence is manifested very early in the storage season.

The most favorable storage temperature, however, can not prevent the final, natural death of the fruit, and at the third and fourth withdrawals of Esopus (Spitzenberg) both lots are past the limit of successful storage, although the lots from 32° F. are still superior to those which have been stored at 35° F.

## COMMON STORAGE.

During the seasons of 1912–13, 1913–14, and 1914–15 a limited number of boxes of apples were stored in well-constructed common storage houses at Hood River, Oreg., and at Payette, Idaho, while comparable lots were held in cold storage at 32° F. As the data obtained were limited, no attempt will be made to present them or to discuss the result in detail until corroborated by further investigation.

As might be expected, however, they indicate that a common storage house cooled by natural circulation only can not take the place of a cold-storage warehouse for long keeping of the fruit. This statement does not in any way belittle the value and utility of common storage houses, as they will always play an important part in the harvesting and storage of the apple crop. The fact that a house of this type can be constructed at the orchard or in conjunction with the local packing house with a much smaller outlay of capital than is required for the construction of a cold-storage warehouse is a strong point in its favor. From the standpoint of a grower or shipper who wishes to hold his fruit for a few weeks or even a few months before placing it in cold storage or finally disposing of it, a common storage warehouse offers numerous advantages. If it is desired to ripen winter varieties, such as Winesap or Yellow Newtown, for an early market, they can probably be more satisfactorily handled in common than in cold storage. Furthermore, the operation of a house of this kind requires no technical knowledge.

The fact remains, however, that during the fall months it is usually difficult in many localities to obtain by natural cooling temperatures that are low enough to permit long storage. During the late fall and winter, however, a temperature very close to 32° F. can be maintained in most sections of the Northwest. The effect of storage of this kind is similar, therefore, in practice to that of a long delay before storage, although the conditions during this delay period are more favorable than the average. It was found, as might be expected, that common storage fruit compared with lots from the same orchards held at 32° F. was yellower, duller, and nearer the end of its storage life at all withdrawals and inspections than the fruit held at the lower temperature.

## DETERIORATION AFTER WITHDRAWAL FROM STORAGE.

It is not only desirable to hold apples in storage with a minimum amount of loss, but of equal importance that this fruit remain in good condition for some time after it is withdrawn and placed on the market. In many instances apples withdrawn from cold storage are reshipped for considerable distances, and in all cases they are in the hands of the wholesaler, retailer, and consumer for several days, oftentimes weeks. Allowance should be made for the length of time it will probably take a particular lot to go into consumption and the temperature and other conditions to which it will probably be subjected. As a general rule, apples should be bright, firm, and not excessively yellowed when withdrawn from storage. In some varieties deterioration in quality will limit the length of time they can safely be allowed to remain in storage. After withdrawal the fruit, of course, should be held at the lowest temperature obtainable.

It has been very generally believed that apples withdrawn from a temperature of 32° F. break down very rapidly under normal outside temperatures and deteriorate faster under these conditions than fruit which has been held at a higher temperature. The experiments show that of two comparable lots, one from 32° F. and one from common storage, withdrawn from storage at the same time, the one from the lower temperature will hold up for a longer period in good condition. In other words, the more successfully and promptly the ripening processes of an apple are retarded the longer it will remain in good condition in and out of storage. If, however, the fruit is allowed to remain in cold storage until overripe, it will naturally break down very rapidly when withdrawn.

In this connection attention is called to Table IV. It will be seen that the amount of decay which developed during the 10-day holding period after withdrawal from storage was in nearly all cases much greater in the fruit stored at 35° F. than in that from 32° F.

## LOCAL VERSUS DISTANT STORAGE OF NORTHWESTERN APPLES.

There is considerable discussion as to whether storage in producing sections is preferable to storage of northwestern fruit in the Middle West and East. While there are good arguments in favor of both systems, at present local storage space is not available for as much as half of the normal apple production of these States. Even if there should ever come a time when adequate facilities for the home storage of the entire crop are available, it would probably be desirable to store a certain percentage of the crop nearer the consuming centers. It therefore seems practically certain that the growers of northwestern apples will utilize, at least for some time to come, both home and eastern storage.

Where apples are stored at points of production in the Northwest, full and due allowance should be made for the time required for shipment to eastern markets and for distribution to the consumers. In most cases it will not be practicable to hold any variety at producing points the full and normal storage period for the variety. Such practices will generally only result in very serious losses from deterioration and decay. Obviously, if a variety has already been held in storage for the maximum period during which it will normally remain in good condition, it can not successfully be transshipped several thousand miles and be delivered in good condition. The different varieties should be withdrawn from storage early enough before the end of their normal storage seasons to permit shipment and distribution while in good attractive condition.

In transferring from warehouse to car, care should be taken not to expose the fruit to much higher temperatures than that at which it was held. When shipped during extremely cold weather every precaution should be exercised to secure such equipment and to take such precautions as are practicable to protect the apples from freezing in transit. In the shipment of apples that have been held in storage for a considerable period the maintenance of uniformly low temperatures above freezing is of especial importance. The rate of development of scald decay and other storage troubles after withdrawal from storage emphasizes strongly the need of maintaining uniformly low temperatures, consistent with safety from freezing, throughout all operations of handling and transportation to the retailer and consumer.

Practically all northwestern-grown apples that are forwarded to eastern markets for storage are shipped as soon as possible after the fruit has been harvested and packed without being placed in cold storage at or near the points of production.

The need of prompt cooling has been strongly emphasized in connection with immediate and delayed storage. It is very evident that whether stored near points of production or several thousand miles distant, the need of prompt and rapid cooling is exceedingly important. When stored near the point of production every effort should be made to get the fruit into the storage house promptly. When intended for eastern storage the apples should be shipped in refrigerator cars under refrigeration. They should be loaded into preiced cars as promptly as possible after harvesting. As the average cooling of a full load of tightly packed and wrapped apples in a refrigerator car is comparatively slow at best, the need of getting the fruit under refrigeration promptly is even greater than if they were going directly into storage. Precooling is an efficient means of securing prompt and rapid cooling and should be utilized wherever facilities are available. Promptness of cooling is essential to good keeping quality, whether effected through precooling or in the car in which the fruit is shipped while in transit.

## THE RELATION OF ORCHARD PRACTICES TO SUCCESSFUL STORAGE.

While harvesting and handling methods, the promptness of storage, and storage temperatures are among the most important factors governing keeping quality in storage, the important relation of orchard practices to successful storage should not be overlooked. It has been noted previously that scald appears first and primarily on the uncolored portion of the apple. In this connection pruning is an important consideration. As it is desirable to procure high color, both from the standpoint of avoiding scald and increasing the market value of the fruit, it is of great importance that the pruning be sufficient to admit enough light to properly color the apple.

As scab and anthracnose are often very serious in storage it is important that proper spraying and pruning methods be followed in order to control these and other fungous diseases. The general good health and vigor of the trees should be maintained by proper cultural and orchard sanitation practices, for sickly trees can not be expected to produce good storage fruit.

## RESPONSIBILITY AND INSPECTION.

The responsibility for the successful storage of apples obviously does not lie with the storage warehouseman alone. In fact, he has largely done his part if the apples are properly stored as soon as they reach the storage house in clean well-insulated rooms held at a uniform temperature of 31° to 32° F. where each grower's fruit of each variety can be examined occasionally and quickly withdrawn to meet the demands of the market.

As has been previously shown, the first responsibility lies with the growers and shippers, since cultural and handling methods largely determine the condition of the fruit when stored. Through his cultural and orchard sanitation practices the grower determines and is responsible for the inherent keeping quality of fruit and its freedom from fungous troubles. Through the care exercised in handling, the time of picking as related to maturity, and the promptness of cooling and storage, the growers and shippers largely determine the life and behavior of the fruit in storage.

As many factors influence the keeping quality of the different lots and as few lots even of the same variety possess the same keeping quality, occasional inspections of representative boxes of each variety from each grower are desirable. In this way the lots most advanced in maturity can in so far as possible be disposed of while still in good condition. The difficulties of making such inspections of all lots in storage are often great. Nevertheless, anyone familiar with the wide variation in keeping qualities of different lots of apples apparently identical at the time of storage will not seriously question the value of such inspection in connection with the disposal of storage holdings in the best merchantable condition.

## COMPARATIVE KEEPING QUALITIES OF VARIETIES OF PACIFIC NORTHWESTERN APPLES.

In order to secure an accurate comparison of the keeping qualities of the more important promising fruit a great many varieties of fall and winter apples were tested in cold storage. These tests were made with lots from North Yakima, Wenatchee, and Spokane, Wash.; Hood River, Medford, and Milton and Freewater, Oreg.; Payette, Idaho; and other sections of the Pacific Northwest. The investigations were extended over a period of four years, during which time approximately 600 boxes of apples were used in these variety tests. All lots were held at a temperature of 31° to 32° F.

Table V gives the varieties on which the data are sufficient to base dependable conclusions. An attempt has been made in this table to arrange the varieties in the order of their keeping qualities. This is based on their market condition, texture, color, quality, flavor, and the amount of decay and skin blemish. It also includes the average dates at which the experimental lots passed prime market condition, and their susceptibility to scald.

In the same connection the notes on the varieties, following the table, are of interest, as they include important factors in connection with the successful storage of each variety.

TABLE V.—*Comparative cold-storage keeping qualities of varieties of Pacific Northwestern apples.*

| No. | Variety. | Average date experimental lots passed prime condition for market. | Susceptibility to scald. |
|---|---|---|---|
| 1 | Rainier | May or later | Practically free. |
| 2 | Hyde King | May | Very slight. |
| 3 | Arkansas Black | do | Do. |
| 4 | Winesap | Last of April | Slight to bad. |
| 5 | Yellow Newtown | do | Do. |
| 6 | Rome (Rome Beauty) | Middle of April | Do. |
| 7 | Northern Spy | do | Slight. |
| 8 | Missouri | do | Do. |
| 9 | Delicious | Last of March | Slight to bad. |
| 10 | York Imperial | First of March | Do. |
| 11 | Winter Banana | do | Slight. |
| 12 | White Pearmain | do | Slight to bad. |
| 13 | Ben Davis | do | Do. |
| 14 | Esopus (Spitzenberg) | Last of February | Very slight. |
| 15 | Gano and Black Ben | Middle of February | Bad. |
| 16 | Stayman Winesap | do | Do. |
| 17 | Salome | | Slight. |
| 18 | Ortley | February | Slight to bad. |
| 19 | King David | First of February | Slight. |
| 20 | McIntosh | Middle of January | Do. |
| 21 | Tompkins King | | Slight to bad. |
| 22 | Wagener | | Bad. |
| 23 | Jonathan | First of January (very valuable) | Very slight. |
| 24 | Arkansas (Mammoth Black Twig) | | Bad. |
| 25 | Grimes | Middle to last of December | Do. |

## NOTES ON THE KEEPING QUALITIES OF VARIETIES OF APPLES GROWN IN THE PACIFIC NORTHWEST.

RAINIER.—The keeping qualities of the Rainier apple are unsurpassed by those of any other variety of the Pacific Northwest that has yet come to the attention of the United States Department of Agriculure. Its ability to retain its firmness, brightness, and quality with almost no decay or skin blemish places it above even the Arkansas Black, Winesap, and Yellow Newtown. In 32° F. cold storage it keeps in prime condition into May or later, and instances are known where large numbers of boxes have been held in excellent condition into September of the year following their harvest.

The department's first record of the Rainier is from the farm of W. W. Scott, at North Yakima, Wash., where there is an orchard of what were wrongly called Hubbardston Pippins. No very accurate or dependable record could be found as to their true name and they were given the name Rainier. The Rainier is of medium size, with rich yellow ground color, mottled and washed with red, splashed and striped with dark red; oblong-conical, irregular, symmetrical, fairly uniform in shape; and of reasonably good quality.

HYDE KING.—The Hyde King possesses valuable cold-storage qualities. It is a large beautifully bluish yellow apple of unusual firmness, which it holds throughout its storage life. Little or no scald occurred in this variety. In the experimental storage lots it usually kept well into May in good marketable condition.

ARKANSAS BLACK.—The Arkansas Black, one of the most important commercial varieties of this section, is also one of the longer keeping varieties. Well-colored and matured fruit remained in prime condition into May. Immaturely picked fruit scalds very badly and decays physiologically much sooner than fruit picked when properly matured.

WINESAP.—The Winesap is one of the most widely grown of the longer keeping varieties. When well colored and matured it kept with little or no decay into the latter part of April. As with most varieties, immature fruits scald badly, although this scald seldom results in physiological decay. In some localities the Winesap often water-cores, but when the water-core is slight the injury to the keeping quality is not as great as with most other varieties.

YELLOW NEWTOWN.—The excellent dessert and culinary qualities of the Yellow Newtown do much to make it a desirable cold-storage variety. It is very susceptible to scald if picked immaturely, and in some sections may develop a browning of the core, which sometimes lowers its market value. Scab is sometimes serious on this variety in storage. Its storage season is usually about the same as that of the Winesap.

ROME (ROME BEAUTY).—When picked at the proper maturity this variety is valuable for cold-storage purposes. However, if picked immaturely very severe scald usually develops in storage. Overmaturity is equally bad, resulting in serious decay. Scald on the Rome Beauty sometimes takes on the appearance of Jonathan spot and later spreads over larger portions of the surface, but more often it is of the common type. Its storage season varied greatly, depending principally on the time of harvesting and the delay between picking and storage, but it generally extended to the middle of April.

NORTHERN SPY (SPY).—On many sites the Northern Spy is very susceptible to bitter-pit, which is one of its worst storage troubles. Bitter-pit often does not make its appearance until some time after packing. The tender skin of this variety is easily broken, with the result that the loss from blue-mold decay may be high. It usually did not keep well after the middle of April.

MISSOURI.—In general the Missouri kept well, with little scald or other deterioration, beyond the middle of April. It has many desirable points as a storage variety.

DELICIOUS.—The Delicious is a better storage variety than its rather delicate appearance indicates. It usually holds its flavor fairly well and is not as seriously affected by scald as are most varieties. It seldom held up well beyond the last of March.

YORK IMPERIAL.—The York Imperial is not a high-quality storage variety, but it held up well until the middle of March. It scalds badly, especially after withdrawal from storage.

BANANA (WINTER BANANA).—When picked at the proper stage of maturity this variety has good keeping qualities. Apples picked when overmature will deteriorate rapidly in storage. Its season usually ended about the first of March.

WHITE PEARMAIN (WHITE WINTER PEARMAIN).—This variety has a high dessert quality which it maintains for a time in storage, but loses in late winter. It often scalds badly, and physiological decay soon follows. The storage season ended about the first of March.

BEN DAVIS.—Like most other varieties in storage, when picked immaturely the Ben Davis scalds badly. When well colored and picked at proper maturity the Ben Davis takes high rank as a storage variety, but its cold-storage keeping qualities do not appear to be as high as many believe. It usually did not keep in good condition beyond March 1.

ESOPUS (SPITZENBERG).—The Esopus retains a good flavor for most of the storage season, and when not picked overmaturely it is a good keeper. Its harvesting season is comparatively short, and fruit that is overmature when picked soon decays. Esopus is exceptionally subject to attack by northwestern anthracnose even in storage. This is an important consideration when the fruit is grown in localities where this disease is prevalent. Generally this variety did not remain in good market condition past the latter part of February.

GANO.—The Gano and Black Ben (the Black Ben is probably but a strain of the Gano, and its storage-keeping quality is similar) are not as good storage apples as is often thought. Their color becomes unattractive, and they are subject to very bad scald. Apples of the variety that are not well matured and well colored should seldom be stored for any length of time. The Gano did not usually remain in the best condition past the middle of February.

STAYMAN (STAYMAN WINESAP).—The high quality and firmness of the Stayman Winesap are retained in storage for some time, but unfortunately this variety is susceptible to extremely bad scald, which is soon followed by physiological decay. To guard against this the greatest care should be taken to store only fruit that is fully matured and well colored. Late picking is also dangerous in some localities, as water-core may develop. The Stayman Winesap passed good market condition about the middle of February.

SALOME.—The keeping quality of the Salome was rather variable, averaging in general not quite as good as that of the Stayman Winesap. It remains unusually bright and attractive through the season, and occasional well-colored lots show excellent keeping quality.

ORTLEY.—For a short storage season the Ortley is often valuable. However, its susceptibility to scab, core browning, northwestern anthracnose, and scald are against its extensive use in cold storage. The scald often appears in small spots resembling Jonathan spot. The Ortley retains its flavor well for a time, but later becomes flat. Most of the Ortleys remained in good condition until after the first of February.

KING DAVID.—For short-season storage this variety is very good. When picked early enough to avoid water-core it can usually be held without serious deterioration somewhat longer than can Jonathan. Excessively early picking, however, encourages scald. It is probable that fruit picked before reaching a total dark red is as attractive as the darker and overmature fruit; and as the storage keeping quality of this earlier picked fruit is unquestionably better, the earlier picking is advised. In general the picking dates should be somewhat before those of Jonathan. King Davids picked under these conditions kept well until the first of February or later.

MCINTOSH.—For short-time storage high-grade McIntosh apples are valuable. Their high dessert quality and comparative freedom from scald are in their favor. In late winter they lose in flavor, and physiological decay soon follows. They remained in good condition until the middle of January.

TOMPKINS KING.—As the Tompkins King water-cores and scalds badly, it is seldom a good storage variety. In cases where well-matured and well-colored fruit is obtained without water-core, successful storage may result, but otherwise this variety is not to be depended on in storage.

WAGENER.—Of the varieties grown in the Northwest, the Wagener is one of the most susceptible to scald. The scald is followed quickly by physiological decay. When well-colored mature fruit is obtained it can be held successfully for a considerable period, as the scald may then be practically eliminated. The average Wageners did not keep much past the middle of January.

JONATHAN.—The Jonathan varies more in its keeping quality than does almost any other variety. In general the earlier harvested fruit keeps better, though very early harvesting results in shriveling and poor flavor. Jonathan spot and soft scald are its greatest enemies in storage. Both are more serious on this variety than on any other that is extensively grown. As delay between picking and storage almost invariably results in both decay and Jonathan spot, immediate storage is particularly important with the Jonathans. They usually passed their best commercial condition the latter part of December.

GRIMES (GRIMES GOLDEN).—Grimes has a short storage season. It holds its flavor fairly well, but ripens quickly and is particularly susceptible to scald. In cold storage it should seldom be held later than the middle or latter part of December.

## SUMMARY.

During the seasons 1911–12 to 1914–15, inclusive, extensive investigations were conducted by the United States Department of Agriculture to determine those factors which are of the greatest importance to the successful storage of the apples of the Pacific Northwest. For this purpose apples were secured from the various more important apple-growing sections of Washington, Oregon, Idaho, and Montana.

The experiments conducted in 32° F. storage showed—

A wide range in the cold-storage keeping qualities of various varieties, depending upon the decay, skin blemish, texture changes, etc., which they develop.

That a 2-weeks' delay between the picking and storage of apples often greatly reduces their life in storage through more rapid ripening and the development of scald, Jonathan spot, scab, and decay.

That a 32° F. temperature will hold apples longer and in better condition than will a 35° F. temperature, the difference in favor of the former increasing with the time in storage.

Immature picking results in severe scald and early decay of apples in storage.

The storage of overmature apples is an equally bad or worse practice than the storage of immature apples, resulting in more rapid deterioration than with those picked and stored at proper maturity.

Well-colored portions of the skin seldom, if ever, develop scald.

Carelessness in handling is responsible for considerable decay of apples in storage, and freedom from bruises and skin abrasions is fundamental to successful storage.

Apples from orchards badly infected with northwestern anthracnose are likely to decay early in their storage life.

Apples in cold storage should be carefully watched and inspected in order that they may be disposed of while in good condition.

In conclusion, it is pointed out that successful cold storage of apples is as much the result of the treatment they receive before being placed in cold storage as of the conditions and temperatures under which they are held in storage. The responsibility rests as much with the producer and handling organizations as with the cold-storage warehousemen.

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HENRY S. GRAVES, Forester

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# INCREASED CATTLE PRODUCTION ON SOUTHWESTERN RANGES.

By JAMES T. JARDINE, *Inspector of Grazing*, and L. C. HURTT, *Grazing Examiner.*

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## BETTER RANGE MANAGEMENT.

This bulletin presents the results of experiments which bear directly on the problem of how to produce more and better cattle on western range lands, a matter of pressing importance in view of the present need for increasing the Nation's food supply.

It is generally conceded that the carrying capacity of the remaining areas of public range is at least 25 per cent less than it was originally, the result of grazing stock at improper seasons and overstocking. It is also a fact that the productiveness of many privately owned ranges, both fenced and unfenced, has been reduced through faulty management. To work out a system of range management and improvement practicable for large grazing units, which will build up the depleted areas and insure the maintenance of the whole range in good condition, is one of the important objects of grazing studies made by the Forest Service on the Jornada Range Reserve, a unit comprising some 200,000 acres in southern New Mexico. The problem involves: (*a*) Finding the system of management that will best bring about natural reseeding of the existing forage plants; (*b*) finding new plants suitable for seeding on the ranges of the Southwest; (*c*) determining the number and distribution of stock-watering places necessary for efficient use of the range, taking into account cost of construction and returns expected; and (*d*) determining the carrying capacity of the range as a means of preventing its being overstocked.

Other and related range problems also have been studied on the Jornada Reserve. One of these has to do with improving the average grade of stock and the average calf crop under range conditions, the possibility of which is generally recognized. Another is how to reduce the losses of stock from lack of feed and water in times of drought and from disease and straying that ordinarily occur in the Southwest. Such losses are a big drain on the profits of the stock industry and often retard, or even prevent, the development of desirable breeding herds.

The studies on the Jornada Reserve are by no means completed; when the length of time during which they will be carried on is considered, it might be said that they are hardly begun. The results so far secured, however, seem to have an important enough bearing on the problem of increased meat production to justify their presentation in a bulletin, to constitute a progress report. They may be modified, of course, by study over a longer period. In estimating the possibilities for improvement, therefore, every effort is made to be conservative. The results are discussed in detail in the body of the text and are summarized at the end.

Naturally, in working with so large a range unit the results are lacking in the degree of refinement obtainable in feed yards and small-scale experiments. This, however, is more than offset by the fact that each experiment, when completed, constitutes its own demonstration on a practical scale.

## JORNADA RANGE RESERVE.

The Jornada Range Reserve is located in Dona Ana County, N. Mex., in the Rio Grande trough, about 50 miles north of the Mexican boundary. It is typical of a large territory in the Southwest which, owing to natural and climatic conditions, will probably always be best adapted to the production of live stock on comparatively large holdings. The Reserve was created by Executive order, May 3, 1912, at the request of the Department of Agriculture, with the idea of securing a complete range unit for conducting experiments and demonstrations in range management under conditions existing in southern New Mexico and similar country in adjoining States. The boundaries were slightly modified by Executive order of April 24, 1916, and at present include about 200,000 acres.

The eastern portion of the area, comprising about one-fourth of the total, is rough and broken and includes the west slope of the San Andreas Mountains, which reach a maximum elevation of about 7,600 feet, both slopes of a narrow belt of rough, gravelly hills just west of the main mountains, and a series of narrow, poorly defined valleys between the two. The remainder of the Reserve is a comparatively flat, or slightly rolling, plain, lying between elevations of about 4,100 and 4,700 feet, and broken only by a small mass of igneous mountains, the Dona Anas, at the southwest corner.

The locality is one of the most arid in the Southwest. Records for 55 years at Mesilla Park, about 15 miles southwest of the Reserve, show an average annual precipitation of 8.63 inches, with precipitation for individual years as much as 17 inches and as little as 3.50 inches. Temperatures as high as 106° are common in summer, and the region is subject to almost continuous high winds and, consequently, high evaporation. The soils of the plain are rather coarse to medium textured wind-blown sands, with patches of heavy adobe clay, usually with a rather high percentage of alkali, where water often stands until evaporated. The soils of the mountains and the outwash plains flanking them are coarse sands and gravels.

Naturally, with this combination of poor soils, low precipitation, high temperatures, and high winds, the vegetation is comparatively thin and made up of drought-resistant, semidesert species. By far the greater part of the forage, perhaps 80 per cent, is furnished by perennial grasses, of which the most important are the grama grasses, three-awn, tobosa, drop-seed, muhlenbergias, burro grass, and wolftail.[1] On large areas of the foothills and mesa, black brush, creosote bush, and mesquite predominate; but black brush and creosote bush are worthless as forage, and the mesquite is of low value. In figure 2 the vegetation is classified into range types for all of the Reserve except the mountain portion.

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[1] Black grama (*Bouteloua eriopoda*) is the most important grass on the Reserve. Blue grama grass (*B. gracilis*) and hairy grama grass (*B. hirsuta*) are found only in the mountains and foothills. *B. curtipendula* is found in the mountains and on the mesa.

Next to the grama grasses in importance are three-awn grasses (known locally as "needle grasses")—*Aristida longiseta*, *A. pansa*, and *A. purpurea*.

Tobosa grass (*Hilaria mutica*).

The drop-seed grasses include several species, the most important being *Sporobolus cryptandrus*, *S. flexuosus*, *S. wrightii*, *S. airoides*, *S. auriculatus*.

The most important species of muhlenbergias are *Muhlenbergia gracillima*, and *M. porteri*.

Burro grass (*Scleropogon brevifolius*).

Wolftail (*Lycurus phlecides*).

Blackbrush (*Flourensia cernua*).

Creosote bush (*Covillea glutinosa*).

Mesquite (*Prosopis glandulosa*).

Originally the only water on the lands now within the Reserve was in a number of mountain springs, few of which furnish any considerable flow. Stock water for the plains and mesa, both on the Reserve and on the adjacent range lands, is pumped from deep wells by windmills and engines or is provided by tanks which catch the flood waters. As a usual thing, there is not enough water for the stock.

Before the lands were placed under reservation in 1912 a number of individuals had attempted to establish permanent stock ranches on them. But the difficulty and cost of sinking permanent wells, the prevalence of droughts, and severe losses discouraged the small owners, and their range rights were purchased eventually by a single stockman.[1] Up to the time the Reserve was created, however, no adequate provision had been made to prevent overgrazing or to effect improvement of the stock. Also, the area lacked adequate facilities for handling and caring for the breeding stock in a way to increase the calf crop and prevent losses. Occasionally a small quantity of concentrated feed was used to supplement the range forage, but for the most part the efforts along this line were unorganized.

## RANGE IMPROVEMENT BY NATURAL REVEGETATION.

If the best results are to be secured in range management, both the requirements of the vegetation which makes up the forage crop and the practical demands of the stock must be kept in mind. These two factors are especially important on year-long ranges of the Southwest, where the time during which there is sufficient moisture for plant growth is so short.

Figure 2 shows that the range in the western portion of the Reserve is largely grama and mixed grasses, which make their main growth during July, August, and September. This forage is usually preferred by animals while it is green, but it cures well on the stalk and is good feed at any time of the year. Consequently it is especially valuable as winter range. The forage of the middle portion of the Reserve is composed principally of grasses[2] which furnish a good class of forage when green, but which have little value as feed when mature and dry. This class of range is therefore of value primarily during the growing season.

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[1] Mr. C. T. Turney, who is cooperating with the Forest Service in carrying on the studies. At the time the Reserve was created the 200,000-acre range unit was conceded to Mr. Turney by neighboring stockmen under common or range rights established through the construction of watering places and the purchase of prior rights and improvements of other owners. He leases all State lands and owns certain private lands around the wells. The Government furnishes the public lands under reservation for a period long enough to reimburse Mr. Turney for expenditures in conducting the experiments. The investigations are planned by the Government and the stockman. All fencing, water development, and other construction work, as well as extra labor in handling the stock for experimental purposes, are paid for by the cooperator in lieu of grazing fees on the Government lands. The Government furnishes the men to keep proper records of all experiments and to aid in planning new investigations.

[2] Tobosa grass, drop-seed grasses, muhlenbergias, and burro grass,

Naturally, therefore, when stock were free to choose between the two classes of range at all times of the year, the grama grass was overgrazed. Further, the grama-grass forage usually was consumed before January, when, if possible, it should have been saved for the period of range shortage from January to the beginning of the summer rains, usually in July.

Mainly to provide for improving the overgrazed grama grass by giving it an opportunity to grow and reseed itself, but in part to reserve a supply of forage for the stock during the critical spring months, the grama-grass range was fenced off from the summer range and divided into pastures.

An area of 34,545 acres, designated on the classification map as Pasture 2, was fenced in the fall of 1912. This area has been used mainly for pasturing steers and poor cows taken from the main herd during the period from January to July. Each season, during the main vegetative growing period of three to four months following the summer rains, beginning in 1913, the number of stock has been reduced to a little less than one-half the average carrying capacity of the pasture. This reduced number is kept well distributed in relation to the four watering places, in order to avoid as far as practicable having any portion of the area grazed heavily. In this way the forage plants are given a chance to develop and produce seed. During the other eight or nine months of the year, mainly after the vegetation has matured, the pasture has been stocked to about 80 per cent of its estimated maximum carrying capacity. Its full capacity has not been utilized, partly as a means of preventing its being overstocked while in course of improvement, but mainly with the idea of insuring a supply of good feed for poor cows from January to July, or later, in case of prolonged drought.

Adjoining this pasture on the west is a large area of unfenced public range, similar in character, but with a larger proportion of the pure grama-grass type. If anything, therefore, it might be considered as a little better than the pasture area. Prior to the completion of the pasture fences in 1912 both areas were grazed throughout the year, with a resulting overstocking during the growing season. Both areas also had suffered as a result of prolonged drought, which killed out a good deal of the grass. They were, therefore, near enough alike in character and condition for purposes of comparison. Yearlong grazing has been continued on the outside range. It is believed, however, that the area has not deteriorated appreciably since 1912, because the seasons of 1913 and 1914 were more favorable than the average for plant growth.

Table I compares the amount and character of the vegetation on these two areas in 1916, after three years' light grazing of the pasture during the growing season.

TABLE I.—*Comparison of vegetation on grama-grass range lightly grazed during the growing seasons of 1913, 1914, and 1915 with that on similar adjoining range grazed yearlong.*

| Distance from watering places. | All vegetation.[1] | | Good forage.[1] | | Medium forage.[1] | |
|---|---|---|---|---|---|---|
| | Pasture 2. | Outside range. | Pasture 2. | Outside range. | Pasture 2. | Outside range. |
| *Miles.* | | | | | | |
| ½ | 506 | 138 | 325 | 0 | 170 | 138 |
| 1 | 484 | 345 | 445 | 148 | 32 | 196 |
| 1½ | 556 | 213 | 517 | 117 | 38 | 94 |
| 2 | 497 | 322 | 481 | 168 | 14 | 145 |
| 2½ | 567 | 340 | 511 | 268 | 54 | 70 |
| 3 | 517 | 328 | 481 | 222 | 21 | 101 |
| 3½ | 529 | 375 | 487 | 208 | 41 | 165 |
| 4 | .......... | 477 | .......... | 351 | .......... | 120 |
| 5 | .......... | 549 | .......... | 516 | .......... | 18 |

[1] Figures represent square centimeters of vegetation on each 10,000 square centimeters of area, based on measurements 1 inch above soil surface.

The changes in amount and kind of vegetation on the Pasture 2 range as compared with the outside range during the three years are shown graphically in figure 1.

The striking features in connection with total vegetation are (1) that in the Reserve pasture it is higher from water out and is as great at less than one-half mile from watering places as that on the outside range about 4½ miles from water, and (2) that on the outside range it is as great at a point about 5 miles from the watering places as it is at any point in the pasture. This last point shows that the outside range is naturally as productive as the pasture, if grazed under the same system of management. Grazing at improper seasons and overstocking, however, have kept the total vegetation at 70.3 per cent of that inside the Reserve.

Total vegetation alone is not, however, a good index of carrying capacity or condition of a range, since on overgrazed areas the tendency is for good forage plants to be replaced by ones of less value. The curves for the amount of good forage plants on the two areas show that there is more good forage one-half mile from watering places in the Reserve pasture than at any point within 3¾ miles from water on the outside area, while Table I shows that there is only 49 per cent as much good forage on the outside range as in the pasture. As in the case of total vegetation, the amount of good forage on the outside range gradually increases with distance from water until at a point 5 miles from water it is as great as at any point in the pasture.

The most striking features in connection with medium forage are (1) that there is more on the outside range than in the pasture, except near water, and (2) that the amount on the outside range begins to decrease at about 3½ miles from water, the point at which the good forage begins to increase rapidly. It will be noted also that in the pasture the amount of medium good forage begins to decrease rapidly at about the same distance from water that the good forage begins to increase rapidly. This fact is important in showing that the good forage plants will eventually crowd out the less valuable species if given a chance to grow.

Besides increasing in density and forage value, the plants on the pasture range have regained their vigor until they produce about 20 per cent more leaves and stems per plant than do similar plants on the outside range.

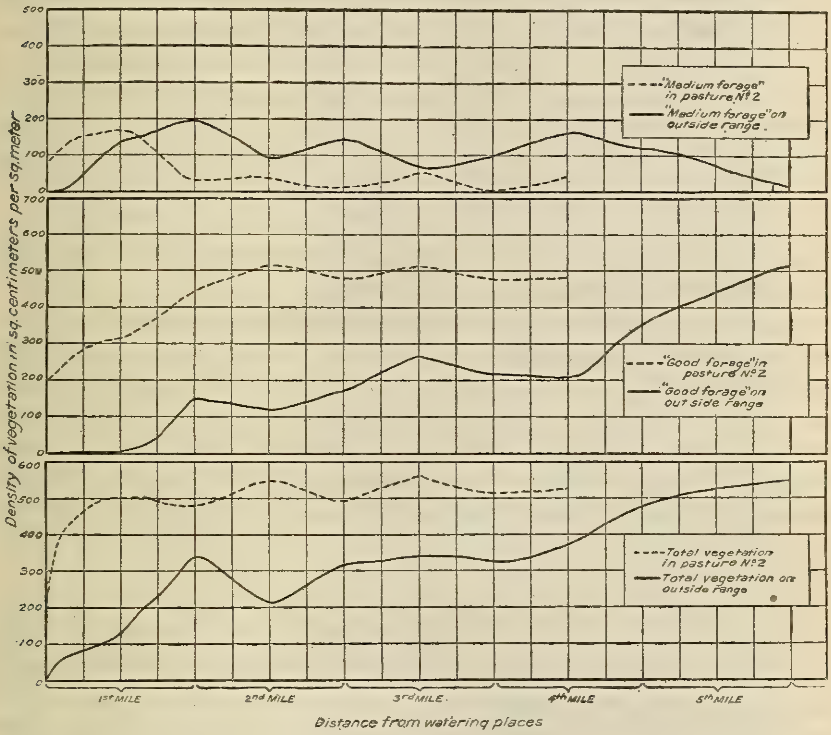

FIG. 1.—Comparative density of vegetation on Pasture 2, Jornada Range Reserve, and adjacent outside range.

Considering the difference in number and kind of plants and the difference in the amount of forage produced per plant, it is safe to say that the range in Pasture 2 of the Jornada Reserve has improved approximately 50 per cent in producing capacity since it was fenced in the fall of 1912, as compared with similar adjoining unfenced range, and that this improvement has been brought about primarily[1] (1) by light grazing (a little less than half the estimated carrying capacity) for three to four months following the beginning of the summer rains, (2) by no overstocking during the other eight months, and (3) by better distribution of stock watering places. It is believed that the area could have been used to full capacity, but not overstocked, during the eight months without retarding the rate of improvement.

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[1] Precipitation considerably above normal in 1913 and 1914 no doubt was an important aid to improvement. The measure of the improvement here given, however, is the difference in condition between the fenced ranges and adjoining unfenced range as a result of three years under different management, both ranges being under the same climatic conditions. The difference in condition reported is attributed, therefore, primarily to the improved management in effect on the controlled range.

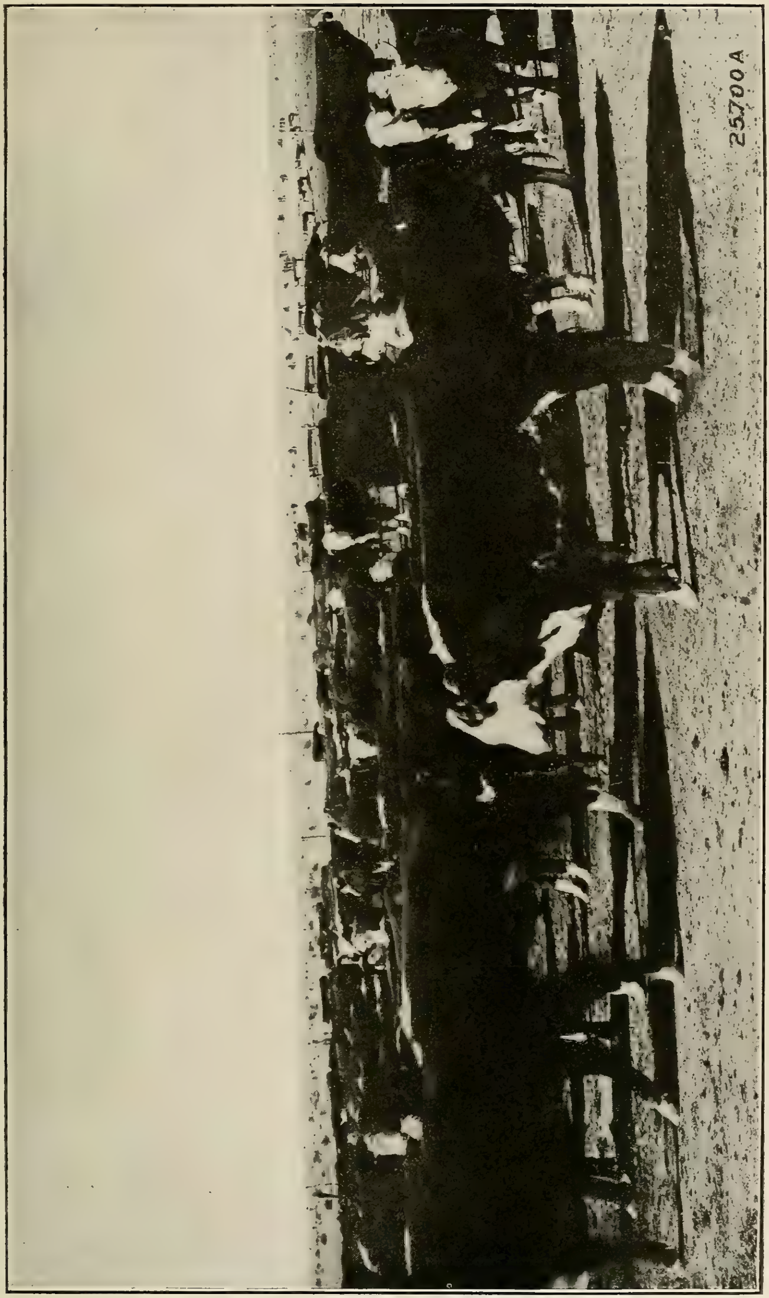
These conclusions are based upon actual count and measurement of vegetation on the two ranges. It is of interest that the practical stockman who has used the range of the Jornada Reserve for 15 years believes that the range of Pasture 2 has improved about 100 per cent since it was fenced in 1913, and that 1 average acre of it is now equal in forage value to 2 acres of the adjoining outside range.

Pasture 5 of the Reserve furnishes additional proof of the value of light stocking or deferred grazing during the growing season. This pasture contains 2,815 acres of grama-grass range adjoining Pasture 2 and similar in character. It is used primarily for saddle stock and as a holding pasture when the stock are being worked. Consequently, grazing has been heaviest during late summer and early fall, when the stock are worked most.

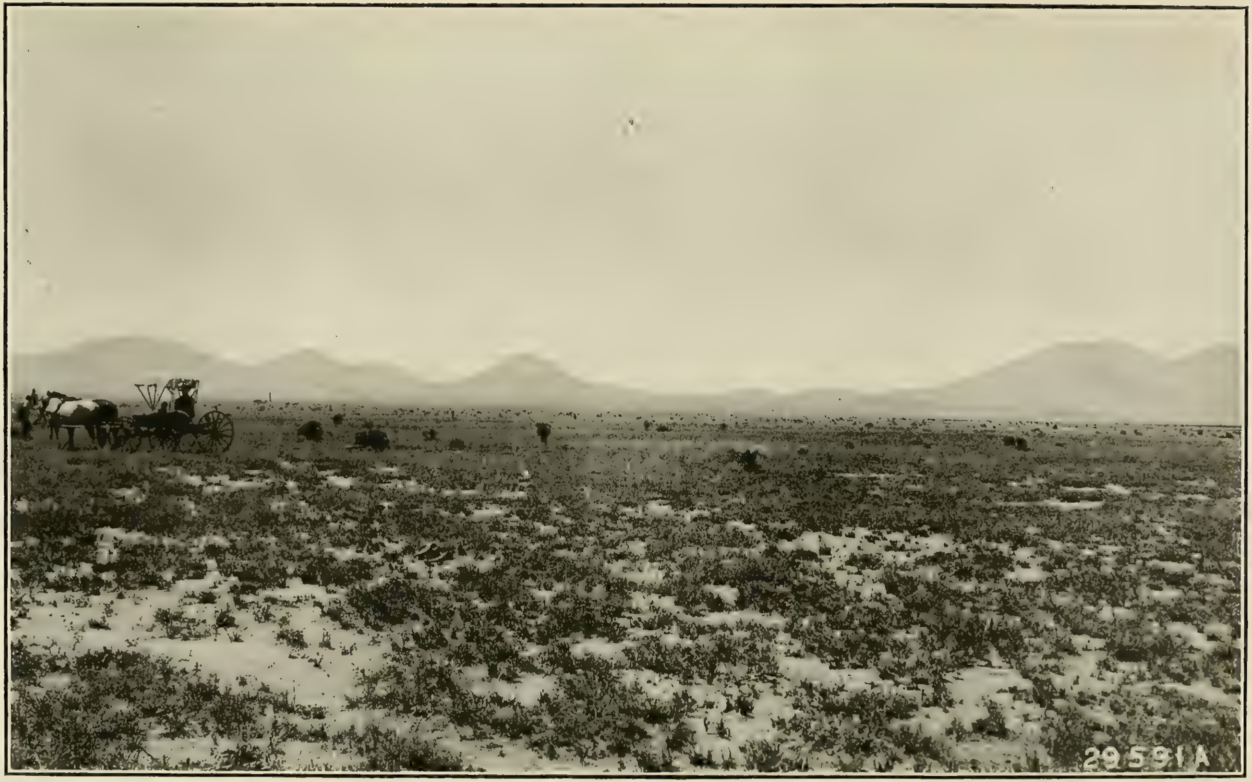
Pasture 5 furnished during 1916 an average of 365 days' feed for one animal on 22.89 acres. Under the present system of heavy grazing during the main growing season this stocking is probably 25 per cent too heavy. The pasture is running down. In its present condition the pure grama-grass area is estimated to have a carrying capacity of 25.5 acres per head, against 20.75 acres per head for similar grama-grass range in Pasture 2. This difference of 22 per cent in favor of Pasture 2 is attributed to light stocking during the growing season.

The area designated in figure 2 as Pasture 10 also is essentially grama grass or mixed grass range, similar to that of Pasture 2. This area, like Pasture 2, has been grazed lightly during the main growing season, but has been utilized fully the remainder of the year. As a whole, the area has improved more since 1913 than any other part of the Reserve. Careful studies show that it is about 10 per cent better than similar range in Pasture 2, this difference being attributed mainly to more productive soil. Pasture 10 produces at least 50 per cent more forage than when it was fenced in 1913.

The rate of improvement of the grama-grass range under total protection against grazing has been studied by means of small fenced areas and the results compared with results secured under light stocking during the growing season as reported for Pasture 2. In both cases the vegetation had been thinned out and weakened by grazing, but there were still enough of the better forage plants left to build the range up by natural revegetation. The results to date indicate that the improvement has been approximately the same



Hereford Steers Produced at the Jornada Range Reserve.



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GRAMA-GRASS RANGE, JORNADA RANGE RESERVE.

This shows pasture 10 after it had been grazed to what was considered the proper degree of utilization, and after the stock had been removed to summer range to give to the grama grass a chance to grow up for winter range.

under protection from yearlong grazing as under protection by light stocking during the main growing season.

The fact that the middle portion of the Reserve is made up largely of tobosa-grass flats, which are primarily summer range and stand heavy grazing during the growing season, has made it possible to remove most of the stock from the grama-grass range while the forage there is making its growth. The summer range, however, may need some protection during the growing season if it is to be kept in the best condition. To this end, additional fences and watering places are being provided as rapidly as possible. The biggest problem on this class of range, however, is believed to be the proper distribution of stock to secure full, even utilization.

For either light stocking during the main growing season or deferred grazing to be successful, there must be enough good forage plants remaining on the range to bring about the improvement desired by natural seeding or by vegetative development. Where the valuable forage plants have been killed out and the soil fertility reduced by water or wind erosion, many years of protection or light stocking would be required to bring about marked improvement. This condition is found frequently around watering places on unfenced range. Figure 1 shows, for example, that there is very little vegetation of any kind and practically no good forage plants within the first half mile out from water on the unfenced range.

There is believed to be no doubt as to the advisability of light grazing of the grama-grass range during the growing season. In the case of the Jornada Range Reserve, the protection of Pastures 2 and 10, for example, aside from improving the range with little loss of forage any year, has made possible the production of steers which brought $2.50 per head more than was paid for the same age and class of stock from unfenced range. Further than this, the reserved feed has made possible the avoidance of loss among poor cows during the spring months and has at the same time been a form of insurance against loss in case of prolonged drought.

Where the whole of a range unit is made up of grama grass or similar grass range, about one-third of the area should be grazed lightly during the growing season two years in succession. Each third of the unit in its turn should then be given as nearly as possible this amount of protection.

## WATER DEVELOPMENT.

The importance of a well-planned water supply for cattle ranges of the Southwest can hardly be overemphasized. Where watering places are from 6 to 15 miles apart, the range near water is overgrazed and denuded, while that away from water is undergrazed. Loss from starvation increases as the distance from feed to water increases, and under such conditions the conversion of grass into meat is generally inefficient.

At best, it is difficult to provide enough water on the Jornada Range Reserve and on other ranges throughout the Southwest. Lack of natural surface water, high cost of boring and maintaining wells, uncertainty of obtaining rain and flood water to fill storage tanks, and low carrying capacity of the range lands all stand in the way. In planning the system of water supply provision should be made first for a few permanent watering places which can be relied upon without fail in time of drought. With these as a nucleus the system should be extended by the construction of enough tanks or other development works to provide for reasonably efficient use of all forage during average years. This may appear to be faulty advice, since in time of drought all the range is needed to tide the stock over; but the expense of providing enough deep wells to insure the proper use of the range is not always justified by the number of stock the range will carry.

Observations on the Jornada Range Reserve to date indicate that fairly good utilization of plains and mesa range can be secured when the stock do not have to travel more than 2½ miles to water. This would mean permanent watering places 5 miles apart, or one to approximately 13,200 acres. On the range where grama grasses predominate this acreage under fence would carry approximately 500 head of cattle. A deep well equipped with pump, windmill, gasoline engine, and storage tank costs from $2,500 to $5,000, depending upon depth of well and current prices of materials and equipment. Add to this the investment in land, if privately owned, and the cost of fences and other improvements, and the total capital invested per head of stock would approximate $100.

As the distance between watering places increases above 5 miles, grazing becomes perceptibly uneven, with a varying degree of overgrazing around water and undergrazing beyond 2½ miles from water. Table I and figure 1 show that on the unfenced range under study the greater part of the vegetation had been killed out for a distance of 1 mile around the watering place, that the total vegetation in the first 2 miles from water is about 50 per cent of what it once was and contains a large number of poor forage species, that on the area represented by the second 2 miles from water the total vegetation is about 73 per cent of what it should be, with a still large percentage of poor forage plants, and that beyond 4 miles from water the range is in about normal condition.

Obviously, the damage to the range in this case greatly reduces the carrying capacity. The loss of both cows and calves during the summer of 1916 was much greater on the adjoining open range than on the Jornada Reserve, where feed was available within a few miles from water. Cases were observed on the outside range where, after grazing out several miles, cows came to water in a weakened condition and drank until they dropped and later died. Where the animals do not die, the inadequate water supply is reflected in the retarded growth of young stock and in the decrease in the calf crop. The poor cows frequently lose or desert their young calves, which then either die or become so stunted in growth that they have little chance of living through the winter.

The question of water supply is a matter of range economics influenced by local conditions, value of range, stock, and cost of development. With present prices it seems safe as a business proposition to advise, for the plains range of the Southwest, permanent watering places on the basis of range for 500 head. This means a distance between watering places of 5 to 6 miles. On the poorer range of the foothills the distance will be greater.

This distribution of permanent watering places will provide for fairly even utilization, but will leave little opportunity for resting the range during the growing season, especially around water, since the animals will tend to graze the green feed near water first. Consequently, the range will be overgrazed for perhaps one-fourth mile from permanent water at best. Where soil and drainage are favorable, it will be economy to supplement the permanent watering places with a number of tanks, each of a size suitable to the situation and the range to be supplied.

In the Southwest the rains are often very local. A small portion of the range may get a good shower, whereas the range a few miles distant may not receive rain during the summer. The cattle naturally drift to where rain has fallen. When there is a tank to catch the run-off, the stock will remain in the vicinity sometimes for weeks, if the water holds out. Meantime, a shower elsewhere may freshen the range and provide temporary water.

With a system of well-distributed small tanks to supplement the permanent watering places, the range around the permanent water can frequently be rested during the growing season. At the same time range away from the permanent water will be used to best advantage; the stock will do better than when they must drift in, even from 2½ to 3 miles, to compete with several hundred others at a set of watering troughs; the cost of operating the pumps or engines will be reduced; and, perhaps most important of all, the feed near permanent watering places will be, to some extent, saved for use during dry periods when the temporary watering places fail.

This system of watering places is being developed rapidly on the Jornada Range Reserve. There are now nine permanent wells, varying in depth from 175 to 500 feet; 11 springs, five of which are of considerable value; one pipe line approximately 8 miles long, with watering places every 2 miles; and 15 tanks which hold water from

2 to 12 months. All of the wells but one were constructed before the range was reserved and are on private land. The pipe line was built in 1916 and carries the water from several mountain springs, a distance of about 8 miles, to range difficult to provide with water by any other means. At the same time it relieves the range and water about the wells. One of the tanks was constructed in 1915 and five during 1916 for the double purpose of getting the cattle nearer water and relieving the range and water about the wells, springs, and permanent tanks.

Of the 15 tanks, one or more caught some of the run-off resulting from practically every shower that fell on the Reserve in 1916. In several instances this allowed the cattle to get onto fresh feed near water and make good gains in condition and at the same time cut down the expense of pumping and gave the hard-used range a rest.

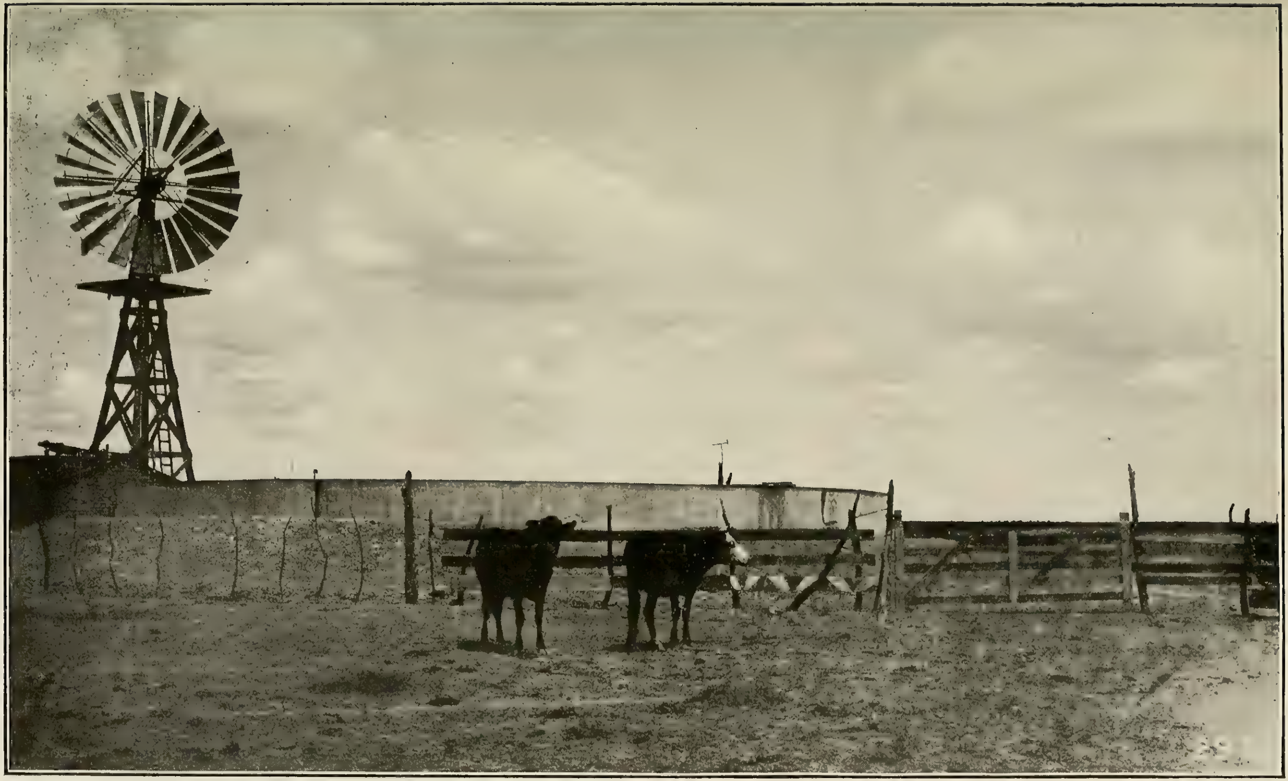
The cost of the five tanks constructed in 1916 was $787, which includes a reasonable compensation for the use of horses and mules employed in the work. The cost per tank varied from $53.40 to $309. The cost per cubic yard of earth in the embankment varied from $0.42 to $1.30, including time of travel between town and the tank site. A large part of the higher cost was for such travel. Even at this high cost the tank is considered a good investment, since it opens up range hitherto little used. The smallest of the five tanks should hold water at least two months after it is puddled and filled once; and the largest about eight months.

The range of the Reserve is now one of the best watered units in southern New Mexico. On about 80 per cent of the area stock do not have to travel more than 2½ miles to water. This will aid materially in carrying the stock through bad years with light losses and in good years will permit of increasing the number of stock. Although the pipe line and five new tanks were not available for use during the dry season of 1916, the fact that the range was as well watered as it was had its part in carrying the stock through with a loss of less than 1½ per cent for the year.

Additional water will be developed, and careful observations will be made with the idea of determining more conclusively the point at which water development for a given type of range ceases to be a good business investment.

## CARRYING CAPACITY.

To decide the number of stock that a range pasture or large range unit will carry year after year is one of the most difficult problems of range management. Private pastures, as well as range lands, are often overstocked and slowly depleted unintentionally through lack of knowledge of their carrying capacity and the effect of the overstocking upon the forage production. The problem is complicated by the following facts:



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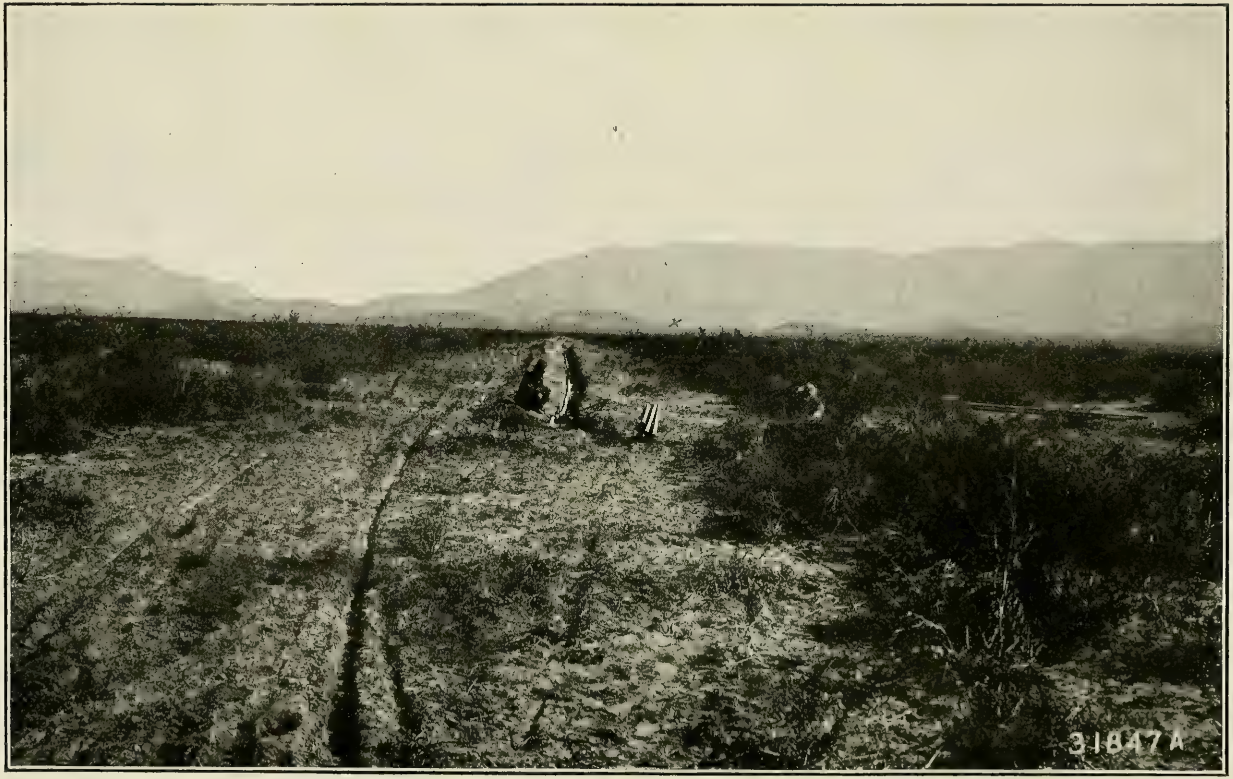
GALVANIZED TANK FOR STORING STOCK WATER.

This tank has a capacity of approximately 100,000 gallons and has less top surface for evaporation and less bottom surface for seepage than shallow earth tanks of the same capacity. The galvanized tank cost $195 at the Reserve; grading cost $128; trampling the earth base and installing tank, $127.40; total cost, $450.40.



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PIPE LINE FOR DISTRIBUTING STOCK WATER.

This pipe line carries water from springs in the mountains, a distance of about 8 miles out across the mesa, and provides water at approximately each mile. Note the loose, sandy soil and the mesquite and black brush with very little grass. × Indicates approximate location of springs.

1. The stand of forage is rarely uniform over any considerable acreage of range lands.

2. Different amounts of forage are produced on the same area in different years.

3. Forage plants vary in power to resist grazing.

4. Other things being equal, the carrying capacity of dry ranges over a period of years is influenced materially by the extent of grazing during the growing season of the vegetation.

5. If there are not enough well-distributed watering places to insure even distribution of the stock and even grazing over the whole area, the range is depleted around water and undergrazed away from water. This may reduce considerably the number of stock the area will carry.

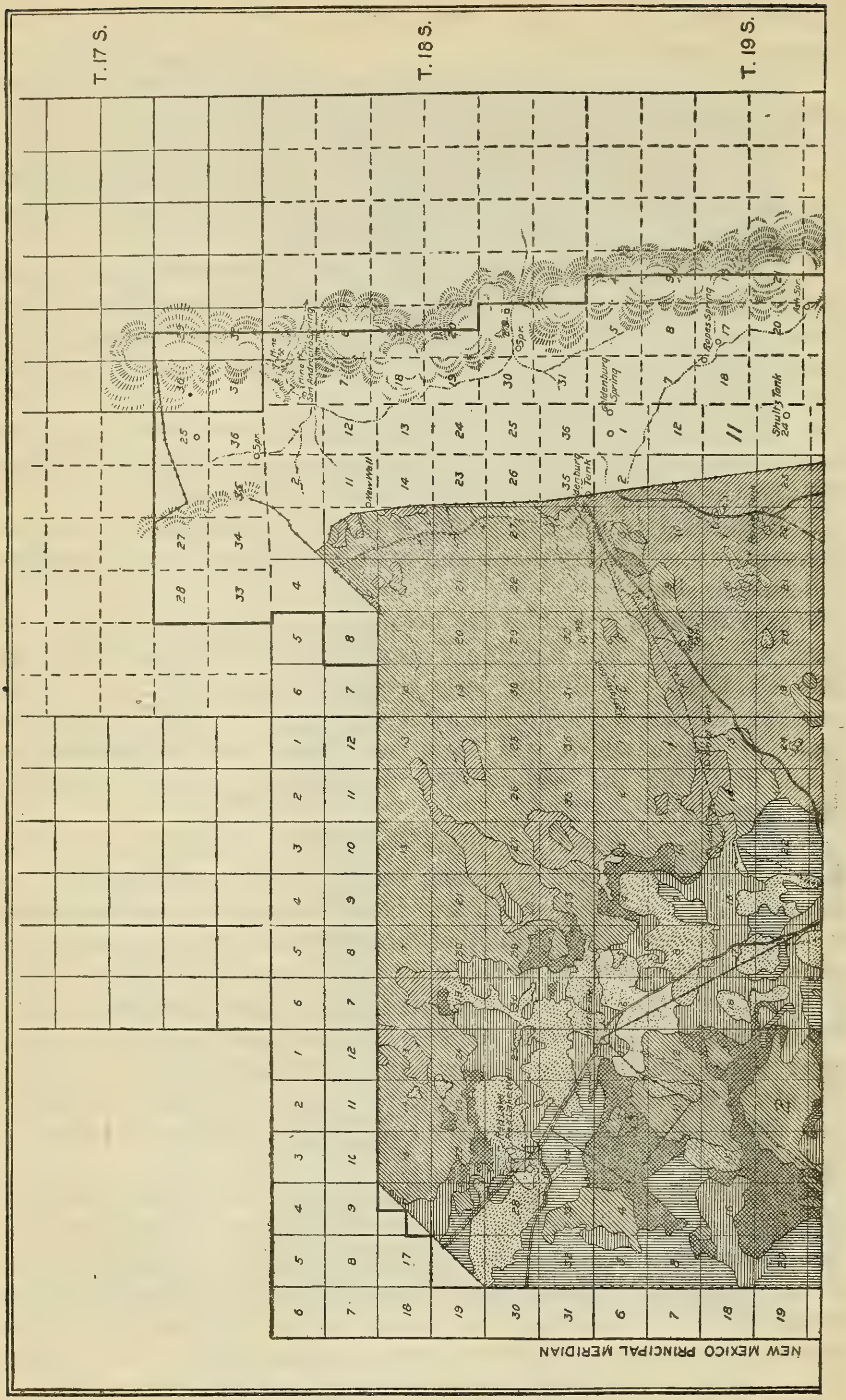
6. The number of stock carried will depend somewhat upon the condition in which the animals are kept—whether merely carried through the period, kept in good condition, or fattened.

7. Reliable data are not available as to the comparative amount of range needed for dry stock and cows with calves, or for yearlings and mature stock.

Where so many variables are involved, it is obviously difficult to work out figures for carrying capacity which will insure 100 per cent efficiency in utilizing large areas of range. It is believed possible, however, to work out figures for the more prominent types of range which will serve as a safe guide in stocking a given unit and in deciding the comparative value of different range areas.

Within the Jornada Range Reserve was found range varying from that which will furnish yearlong feed for one mature animal on about 20 acres to that which will barely support a mature animal on, perhaps, 100 acres. Further, the different types of range are somewhat intermixed. To determine the comparative grazing value of the different types, a range survey was made of approximately 150,000 acres. As a result of this, the area has been divided into eight more or less distinct types and an estimate made for each of the stand of vegetation the stock will eat. This type classification, along with pasture divisions and watering places, is shown in figure 2.

For each of the 13 pastures of the Reserve record has been kept of the number of animal days' feed furnished each month and year, and of the percentage of the vegetation left unused or the percentage of overstocking. From these data and the data secured by the classification and grading of the range, tentative figures of carrying capacity have been worked out. They will, of course, be amended when necessary to conform to results over a period of years.


T. 17 S.
T. 18 S.
T. 19 S.
San Andreas Spring
New Well
Oldenburg Spring
Oldenburg Tank
Ropes Spring
Shultz Tank
Ash Spr.
Spr.
NEW MEXICO PRINCIPAL MERIDIAN

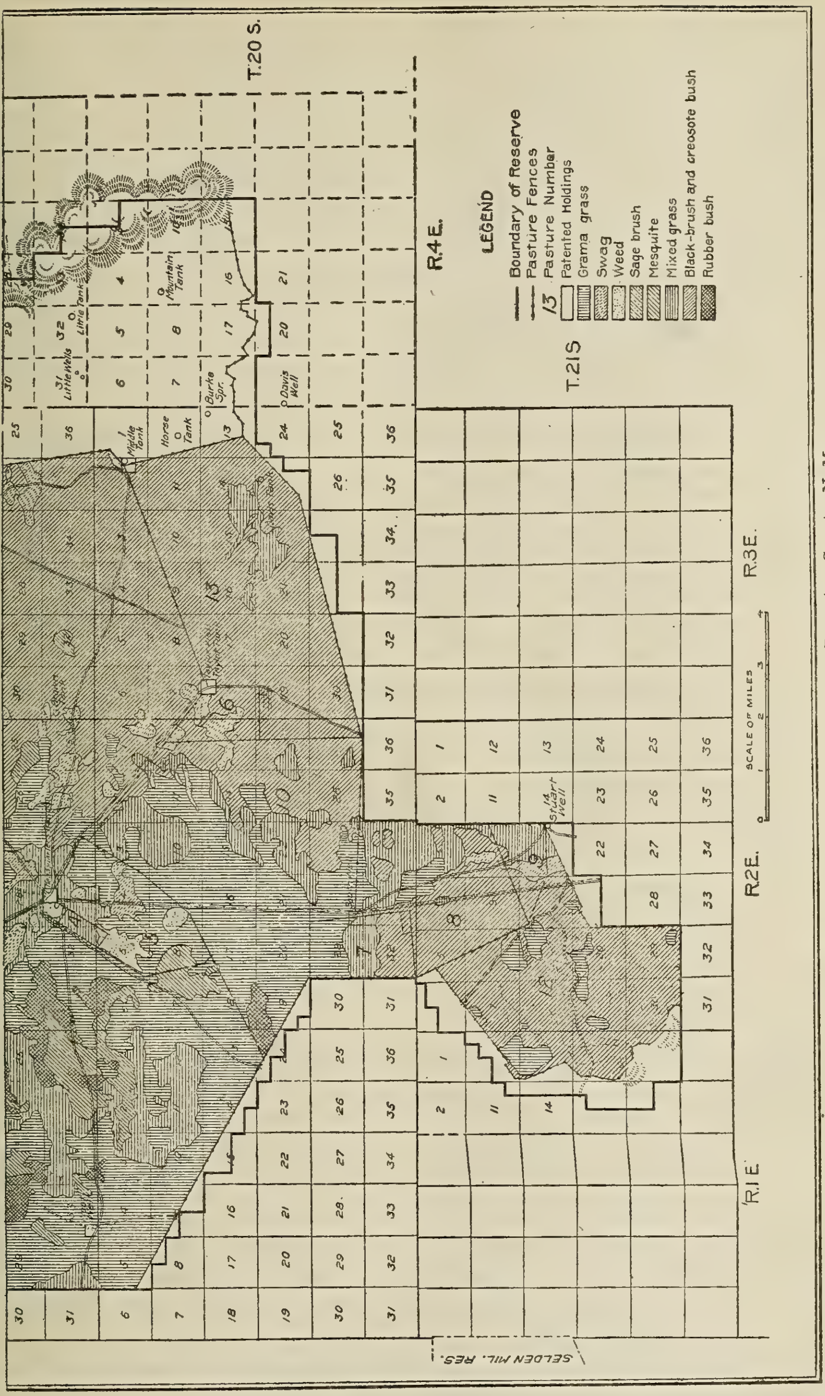


FIG. 2.—The Jornada Range Reserve, Dona Ana County, N. Mex.

### THE RESERVE AS A WHOLE.

Of the 202,000 acres of the Reserve, approximately 10,000 acres of the mountain area are inaccessible, leaving about 192,000 acres either fully or partly used. From May, 1915, to April 30, 1916, the average number of stock grazed, including weaned calves and horses, was 4,632.16, or an average of one head to 41.45 acres of usable range. Taking into account the surplus or shortage of forage in each of the 13 pastures, the estimated carrying capacity of the whole Reserve in its present condition and stage of development is 5,030 head throughout the year, not including unweaned calves. This is at the rate of 38.1 acres per head. The Reserve would no doubt carry this many, provided, as at present, supplemental feed were used to prevent the loss of poor cows. This would be necessary in a measure if only 4,000 head were grazed, as there would still be some stock in need of special attention. These figures for the Reserve as a whole are of interest merely as showing average carrying capacity over large territory, combining plains, foothills, and mountain range, such as is found throughout southern New Mexico outside of the National Forests.

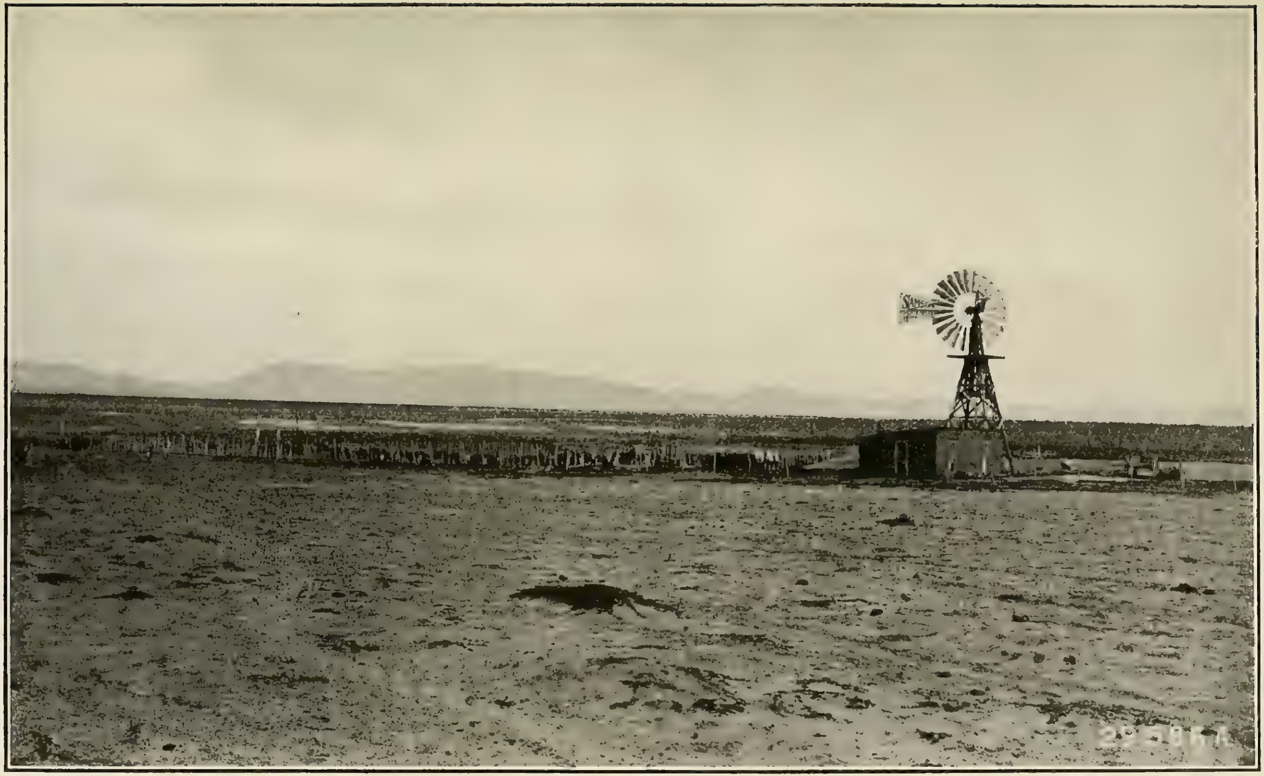
As a whole, the range of the Reserve is in better condition than the unfenced ranges and is better supplied with stock-watering places. Aside from these advantages, better utilization can be secured under fence. Consequently, for a similar area of unfenced range in its present condition and development 50 acres per head would be a conservatively low figure, if the range and stock are to be kept in reasonably good shape. The carrying-capacity figures for the main types of range, however, will serve as better guides in estimating the number of stock a given range should support.

### GRAMA-GRASS (WINTER) RANGE.

#### JORNADA RESERVE.

The plains where grama grasses form the bulk of the forage constitute, perhaps, the most important type of range in the Jornada Range Reserve and vicinity. The investigations to date show that this type in normal condition, if grazed lightly during the main growing season, will furnish 365 days' feed for one animal per year on from 20 to 30 acres, according to the proportion of range types other than grama grass.

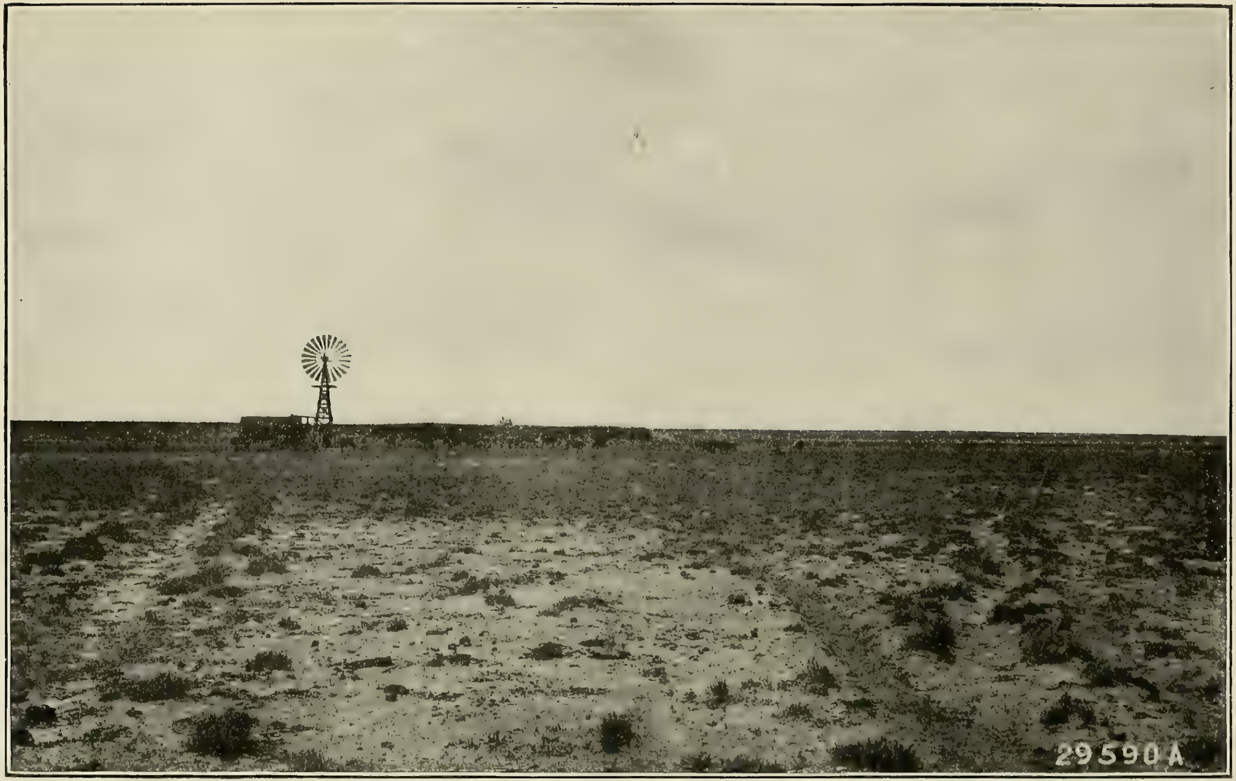
Pasture 2 of the Reserve (fig. 2), containing 34,545 acres, has supported an average of 1,045 head of stock, yearlings and above each year for three years—May 1, 1913, to May 1, 1916. From May 1, 1913, to May 1, 1914, it supported an average of 1,260 head. It is estimated that the surplus feed averages 20 per cent of the total. The pasture, then, if fully utilized, would have carried an



F-29586A

OVERGRAZED RANGE NEAR A WATERING PLACE JUST OUTSIDE THE JORNADA RANGE RESERVE.

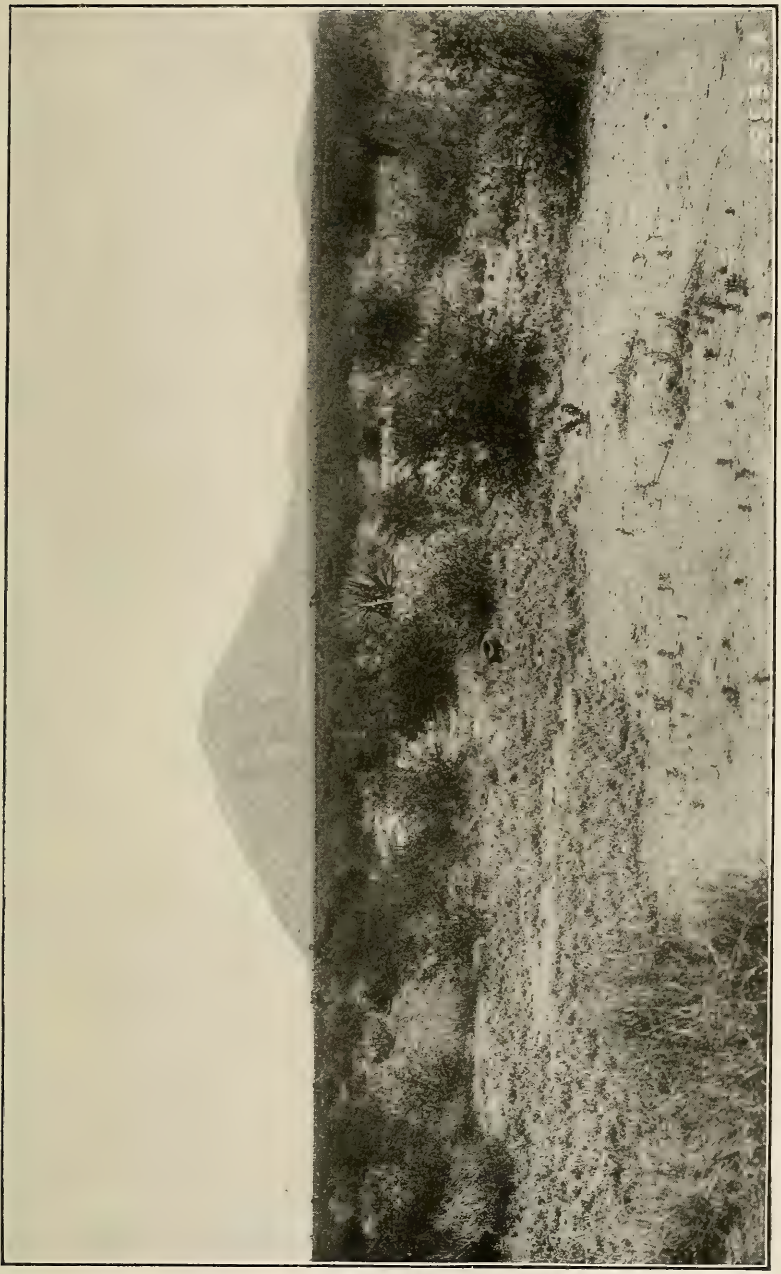
Virtually all the vegetation has been destroyed by overgrazing and trampling brought about by congestion of a great many cattle on inadequately watered range.



F-29590A

WATERING PLACE ON THE JORNADA RANGE RESERVE.

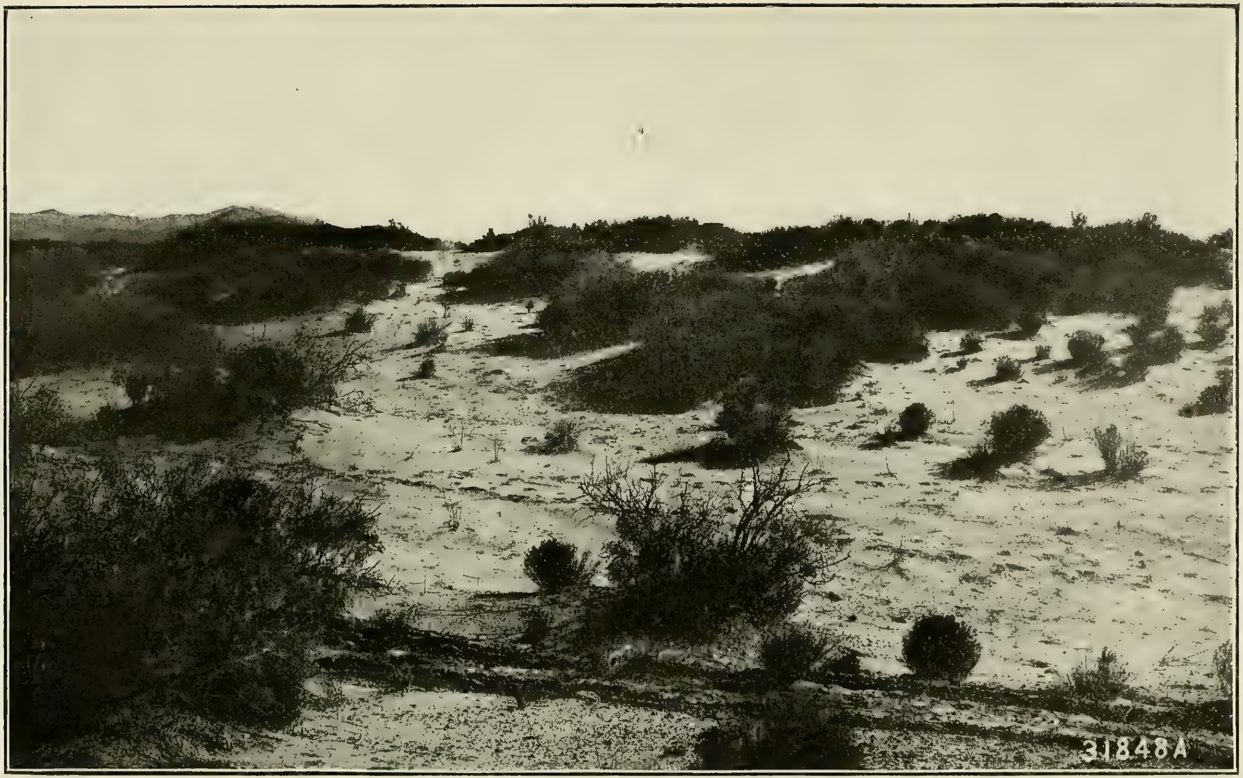
Contrast with watering place on adjoining outside range, Plate V. Vegetation here extends up to the well.



F-29595A

BLACK-BRUSH TYPE. SCATTERED STAND OF BLACK BRUSH (FLOURENSIA CERNUA) WITH TOBOSA GRASS (HILARIA MUTICA) AND BURRO GRASS (SCLEROPOGON BREVIFOLIUS) GROWING BENEATH THE BRUSH.

This type occupies several thousand acres of the Reserve. It is often referred to as "summer range."



F-31848A

TYPICAL SANDHILL MESQUITE TYPE.

Very little forage is produced on this type of range.

average of 1,307 head, or at the rate of 26.4 acres per head for all types of range together.

In Table II the grazing value of the various other range types in Pasture 2 are compared with that of the grama-grass type.

TABLE II.—*Acreage and carrying capacity by types of range in Pasture 2, Jornada Range Reserve.*

| Type of range. | Acres in Pasture 2. | Acres of other types equivalent to 1 acre of grama grass in forage value. | Average[1] acres per head per year when 80 per cent is utilized. | Estimated average acres per head per year when fully utilized. |
|---|---|---|---|---|
| Grama grass | 14,473 | 1 | 25 95 | 20.76 |
| Tobosa grass | 1,658 | .92 | 24.56 | 19.64 |
| Mixed grasses | 6,514 | 1.08 | 28.06 | 22.44 |
| Weeds | 721 | 2.42 | 62.83 | 50.28 |
| Sagebrush sandhill | 423 | 1.59 | 41.50 | 33.20 |
| Mesquite sandhill | 5,922 | 2.98 | 74.09 | 59.27 |
| Rabbit bush | 4,834 | 2.10 | 54.59 | 43.67 |

[1] Average of 3 years, May 1, 1913, to April 30, 1916.

The condition of the grama-grass range of Pasture 2 is now about normal. In this case about 21 acres per head, yearlings and above, will furnish 365 animal-days' feed over a period of years, provided the range is not stocked heavier than approximately one animal to 40 acres during July, August, September, and October. During the remainder of the year enough additional stock can be grazed to make up for the reduction during the growing season.

This conclusion is substantiated somewhat by the records for Pasture 5 (fig. 2). The grama-grass range of Pasture 5 actually furnished 365 animal-days' feed per 20.4 acres during the year from May 1, 1915, to April 30, 1916, though the heaviest grazing was during late summer and fall, when it should be light. Study of the vegetation on this pasture shows that the condition of the range is only approximately 75 per cent as good as similar range in Pasture 2. This and the fact that there was a shortage of feed in Pasture 5 led to a decision that the pasture was 25 per cent overstocked during 1916. With a reduction of 25 per cent in the total grazing during the year, and light stocking during the growing season, it is estimated that the forage production can be increased 25 per cent in three to four years. The area will then carry stock at the rate of 365 animal-days' feed annually on from 20 to 21 acres of the grama-grass area. If heavy grazing during the growing season is continued, the carrying capacity will, without doubt, be further reduced.

These two pastures are typical of large areas of plains range where the grama grasses predominate. For such range in good condition, therefore, approximately 27 acres of the combined types, or 21 acres of grama-grass type alone, will furnish 365 animal-days' feed per year, for yearlings and above, over a period of years, provided it is stocked at not more than one-half this rate during July, August, September, and most of October. In case of prolonged drought, supplemental feed will probably be necessary. Conditions resulting from extremely prolonged drought should be met by some plan similar to that suggested under prevention of losses, rather than by greatly understocking over a period of years.

### UNFENCED RANGE.

A rough classification was made of unfenced range[1] joining Pasture 2 and similar in character. Of approximately 98,530 acres, about 66,485 is grama-grass type, and the remainder of other range types of less grazing value than the grama grass. The best information available indicates that this area has been grazed by a yearly average of about 3,750 head of cattle, yearlings and over, an average of 26.3 acres per head for all types. One acre of the grama-grass range was estimated as equal to 2¼ acres of the other types. On this basis the total of 98,530 acres would be equivalent to 80,725 acres of grama grass, or an average of 21.53 acres per head.

This range was considered overstocked at least 25 per cent for the quantity of feed it produces, to say nothing of the absence of a chance to recuperate. The estimated carrying capacity for the area as a whole in its present condition, therefore, is about 35 acres per head, and for the grama-grass type 27.9 acres per head. The estimated carrying capacity of grama-grass range in Pasture 2 of the Reserve is 20.76 acres per head, or 34.4 per cent greater than that of this outside range of similar character.

In the discussion of range improvement by natural reseeding it was shown that the total amount of vegetation on this outside range is only 70.3 per cent of that in Pasture 2, and the good forage only 49 per cent, and the conclusion was drawn that Pasture 2 has increased approximately 50 per cent in forage-producing capacity since 1913. This apparent discrepancy between the conclusion relative to the two ranges based upon vegetation studies alone and that based on the number of stock actually carried is accounted for by several facts. First, the stock in Pasture 2 have been carried in good condition, and poor cows have actually improved during critical periods of the year. Stock on the outside range have merely been carried over, with some loss from starvation. Second, the estimates of surplus feed in Pasture 2 were purposely low, and the estimates of overstocking on outside range were likewise low. Further, the data as to number of stock on the outside range are estimates only.

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[1] The range here referred to is described under the chapter on range improvement by natural revegetation, page 5.

These differences in intensity of utilization and condition of the stock, together with the conservative estimates where actual measurement or count was not possible, will more than account for the 15 per cent difference in forage produced and number of stock actually grazed. Considering that the problem was approached by two independent lines of study, the result is thought to justify the tentative conclusions.

### SUMMER RANGE.

The other types of range are so intermixed that on no large area of any one has it yet been possible to obtain accurate figures of carrying capacity. For the combination of types, however, making up what may be considered the summer range, including the tobosa-grass and burro-grass flats, and the black brush-creosote bush type extending from the flats into the foothills, the figures for the area designated in figure 2 as Pasture 13 are fairly representative.

This pasture contains 9,517 acres, of which 8,912 is a combination black brush-creosote bush type. It receives the surplus run-off from an area twice to three times its size. There are many small flats which flood and which have a high carrying capacity for summer range. The general average, however, is greatly lowered by the dry ridges and slopes which support little but creosote bush or black brush of no value as forage. Black grama and other grasses among the brush type furnish considerable feed on the drier parts of the flats.

During 1916 this pasture was grazed heavily in summer and lightly in winter, and furnished, on an average, 365 days' feed for one animal (cows, with unweaned calves, and bulls) on 37.4 acres. The area is, perhaps, a little better than the average for this class of range. Pasture 1, containing 74,714 acres, furnished yearlong grazing during 1916 at the rate of 45.2 acres per head. It was estimated to be only 90 per cent stocked, which would give a carrying capacity, if fully stocked, of 40.7 acres per head. The indications are that this class of range as a whole will support one animal throughout the year on from 38 to 45 acres, according to the proportion of flats subject to flooding and to the extent of the range similar to that shown in Plate VIII.

### MOUNTAIN RANGE.

The lower hills and mountain range on the west slope of the San Andreas Mountains in 1916 furnished 365 days' feed for one animal (yearlings and horses) on each 53.33 acres. The area was regarded as about 15 per cent overstocked, since the animals did not hold up well, and portions of the range near water were slightly overgrazed. This area, therefore, will support only one head to each 60 acres until more water is developed. There are a number of barren areas and inaccessible spots. Three additional stock-watering tanks were constructed in 1916, which will slightly increase the carrying capacity and aid in bringing the stock through in better shape. The general character of this range is shown in Plate IX.

## INCREASE IN CALF CROP AND IMPROVEMENT IN GRADE OF STOCK.

Reports received from stockmen during 1914 in connection with an investigation of live-stock production on western ranges showed an average calf crop of 66 per cent for New Mexico and 57 per cent for Arizona.[1] This figure for New Mexico as a whole is believed to be too high for the ranges of the southern part of the State. Granting that it is not, however, there would still seem to be a good chance for a bigger calf crop, provided it is practicable to keep the breeding stock, both cows and bulls, in better condition throughout the year and to secure the proper distribution of bulls.

In giving the additional feed and care required for an increase in the calf crop, the possibility of improving at the same time the average grade and value of the individual animal should not be lost sight of. Supplemental feed should be given to a cow or bull capable of producing a calf worth $30, in preference to an animal capable of producing a calf worth only $25 or $27.50. Preference should also be given an animal capable of producing a steer with the qualities necessary for good feeders.

When the studies to determine the possibilities of increasing the calf crop and improving the grade of stock were begun in 1915, the female stock of breeding age on the Jornada Range Reserve numbered approximately 1,950 head. The bulk of these were fairly good grade Herefords; but about 500 or 600 head were of low grade, off color, and old Mexico stock.

Five hundred of the best Hereford cows and heifers and 20 of the best Hereford bulls were selected in the summer of 1915 and given a summer pasture and a winter pasture away from other stock. In November the cows were dehorned and branded with a special brand for this herd and its increase. The record started November 19, 1915, with 500 cows, 20 bulls, and no calves.

Early in 1916 the 20 bulls were replaced by registered Hereford bulls purchased in the Panhandle of Texas. The least desirable of this lot have, in turn, been replaced by the pick of a carload of registered Herefords purchased of the Kansas Hereford Breeders' Association in November, 1916.

Until February 1, 1916, both female stock and bulls were left on the range. The bulls and a few thin cows about to drop calves were then placed in a small pasture and fed cottonseed cake to supplement the range feed. The number on feed was added to from time

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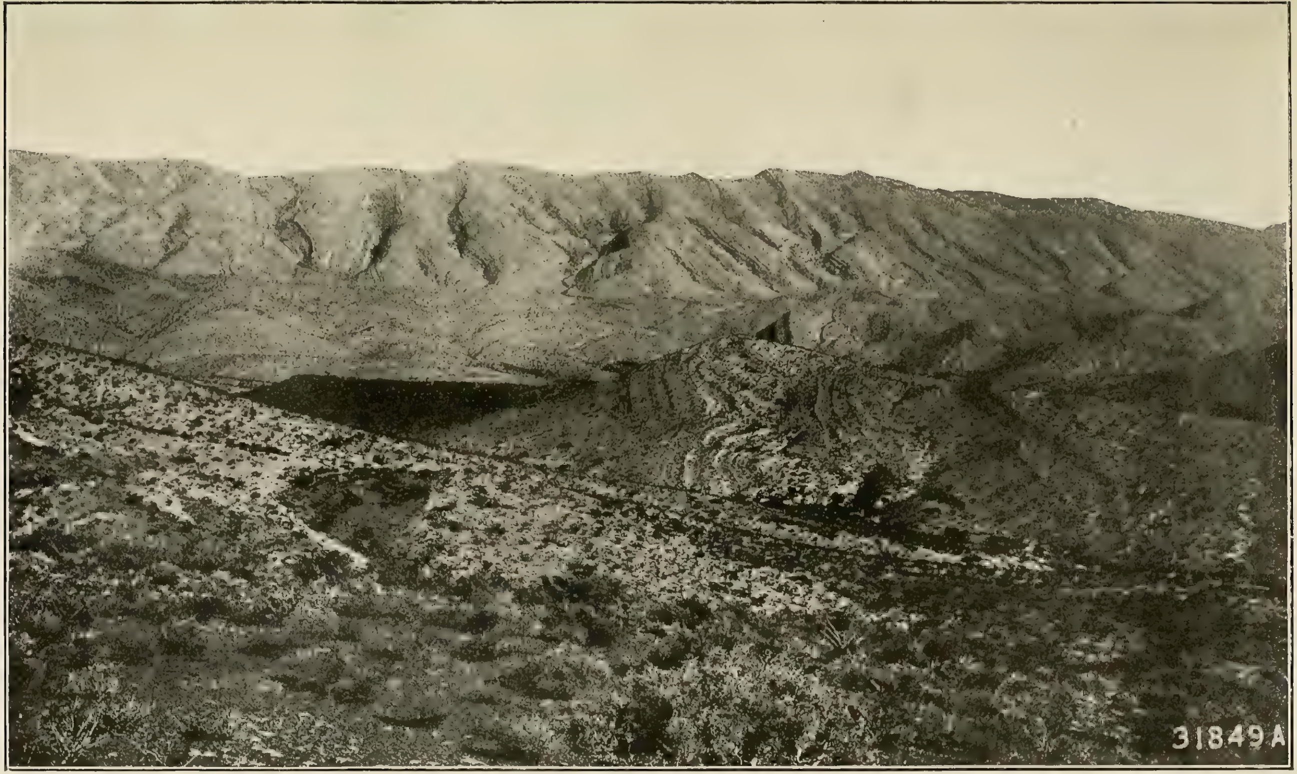
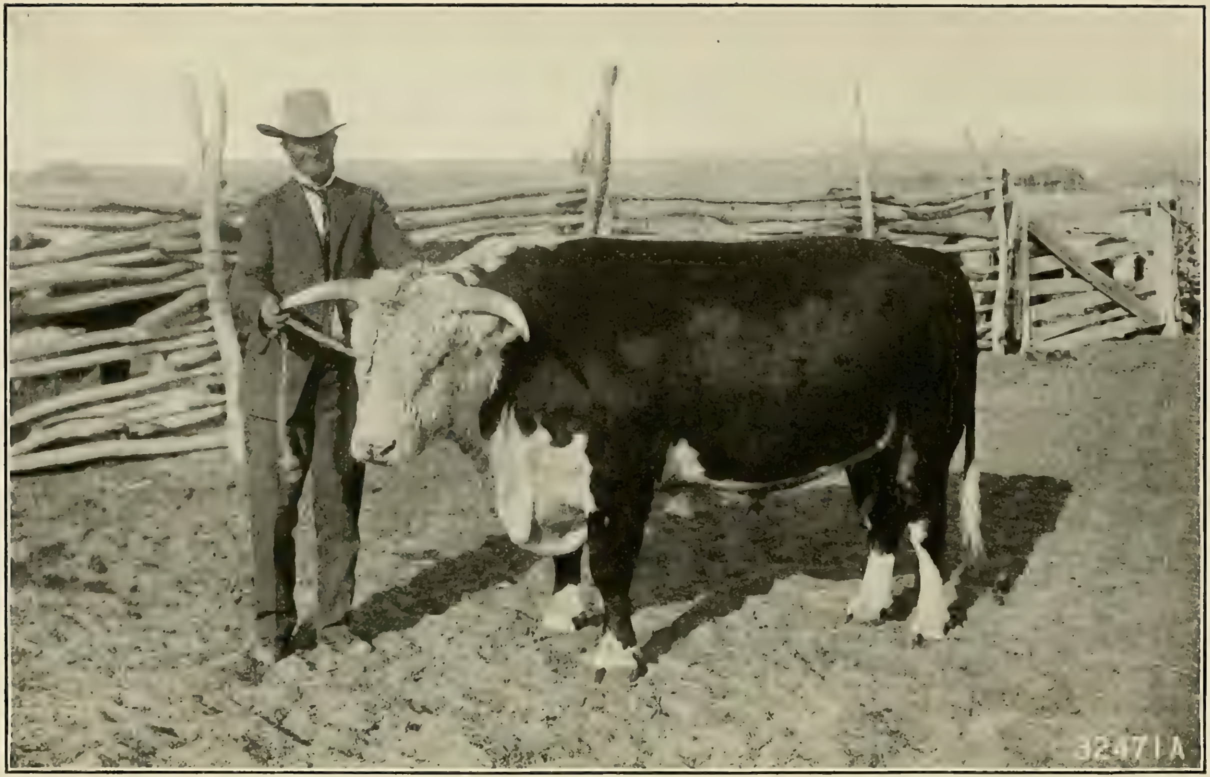
[1] Report 110, U. S. D. A. The Meat Situation in the United States, Part II, p. 23.



F-31849A

TOPOGRAPHY AND VEGETATION OF SAN ANDREAS MOUNTAINS, JORNADA RANGE RESERVE.

This shows the sparse vegetation and steep, rocky slopes. The carrying capacity of this area is about 60 acres per head.



F-32471A

TYPE OF BULL USED IN THE SPECIAL 500-HEAD HERD BREEDING ON THE JORNADA RANGE RESERVE.

This bull weighed 1,720 pounds in breeding condition when 2½ years old.

to time until, by the end of March, 225 head were being fed a small quantity of cottonseed cake each time they came to water. The feeding was discontinued April 19, when the grass started to grow. The spring was a dry one, however, and range forage practically stopped growing in early June. Consequently, 146 cows with small calves were again started on cottonseed cake on June 7 and fed to to July 19. The cows were not in danger of starvation, but were thin. The feeding was done primarily to keep them in thrifty condition so as to insure, if possible, a good calf crop the following year.

During the feeding from February 1 to April 19, a total of 18,850 pounds of cottonseed cake was fed in 15,588 feeds, or slightly over 1 pound per head at each feeding. A total of 6,800 pounds was fed in 3,528 feeds during June and July, making a total of 25,650 pounds of cake fed during the year. If all of the 500 cows and 20 bulls are considered, this would amount to slightly less than 50 pounds per head.

In the matter of range the special herd had no advantage over the other stock except to be by themselves. This made it possible to watch them more closely and pick out those in need of special feed. Approximately half of one man's time was spent in caring for the herd. This involved riding the fences, looking after watering places, feeding, and general care.

From the beginning of the herd record, November 17, 1915, to November 17, 1916, a total of 406 calves were branded. With a herd of 500 cows, this amounts to a calf crop of 81 per cent. Over 96 per cent of the calves had good Hereford color and markings and for the most part had good backs, straight tops and underlines, and as a whole showed up well. It is true that the experimental herd were selected cows, and it is possible that the selection of a number of 2-year-old heifers slightly increased the number of calves. This advantage, however, was probably offset by the extra handling of the stock when they were selected, dehorned, and branded, and by the dry year. It is hoped that an average calf crop of 81 per cent or better can be produced without materially increasing the quantity of supplemental feed.

The loss for the year amounted to five cows and, so far as known, five calves, four of which died before branding. This loss of approximately 1 per cent is exceptionally small and probably will be exceeded slightly in future years, even with more favorable range conditions and better care. It is believed, however, that the average loss in this herd can be kept within 2 per cent for cows and 4 per cent for calves.

Selection of the 500 cows for the special breeding herd left about 1,450 female stock of breeding age in the main herd on the Reserve.

Most of these were run throughout the year on Pasture 1 (fig. 2), containing 74,714 acres, mainly of the black-brush and creosote-bush type, and rolling mesquite and sandhill range, with a small proportion of tobosa-grass flats. During the summer of 1915, 325 low-grade, off-color, and otherwise undesirable cows were cut out and sold in one bunch, and a number of others were butchered for the local market. In the fall of 1916 a lot of 101 head were cut out and sold as "canners." The culling of nearly 500 head and their replacement by heifers of good Hereford grade has improved vastly the appearance as well as the average grade and value of the breeding herd. Similar culling has been done among the bulls and will be continued each year. Sales will be made primarily from the culls and from the less desirable heifers produced, reserving selected heifers for the ranch herd.

The management of this main herd was similar to that of the special herd, but less intensive. About 75 per cent of the bulls and 2 per cent of the poorest cows were fed cottonseed cake at the rate of 1¼ pounds per head each time they came to water, usually every day, during February, March, and April. The stock of this herd were not maintained in as thrifty condition as those of the special herd during the early spring, but were equally as good in late summer and fall.

From 1,522 cows, 1,053 calves, or 69.2 per cent, were branded in 1916, as against 81 per cent for the special herd, making an average of 72 per cent for the Reserve as a whole.

The known loss from this herd was 8 cows, a little over one-half of 1 per cent, and 11 calves, a little over 1 per cent. The pasture is large and rather rough and brushy, making it difficult to determine the loss with absolute accuracy. The whole area was worked thoroughly several times during the year, however, and it is not probable that any appreciable loss was overlooked.

On a unit as large as the Jornada Range Reserve it is difficult to get accurate records of the calf crop, even when under fence, and next to impossible to secure corresponding data for large herds on adjoining unfenced range. From such data as could be secured it seems doubtful whether the average calf crop on range lands in southern New Mexico in 1916 was as high as 60 per cent. This figure is believed to be rather high for the calf crop over a period of years back. Even taking as an average the 66 per cent calf crop reported by stockmen for New Mexico as a whole, the average calf crop of 72 per cent for Jornada Reserve, with 81 per cent for the special herd, shows marked possibilities.

The most important single factor influencing the calf crop under conditions such as those on the Jornada Reserve is the condition of the breeding stock. Cows which are barely able to totter to and from feed and water can not be expected, after dropping a calf, to breed as soon again, or in as large proportion, as those which are kept in thrifty condition. Unless the range is supplemented by concentrated food, a large percentage of cows, especially those suckling young calves during the winter, are very thin in flesh and low in vitality by the time green grass comes on southern New Mexico ranges.

The biggest possibility for increasing the calf crop lies in keeping these cows, not fat, but strong and thrifty enough to enable them to breed promptly, and in feeding the bulls so that they will be able to do the work expected of them. Although the one year's results at the Jornada Range Reserve do not justify final conclusions as to the results, over a period of years, from better care and the use of supplemental feed, they do justify serious consideration by stockmen of employing this means to increase the calf crop.

Beginning in 1917, from 50 to 75 of the least desirable cows originally selected for the 500-head special breeding herd will be culled out and replaced by heifers selected from the 1915 calf crop of this herd. These heifers will be kept from the bulls until approximately 20 months old, since it is believed that the general practice in the Southwest of breeding yearling heifers has a tendency to decrease the average size of the stock and to increase loss, without increasing the number of calves produced over a period of years sufficiently to compensate for the disadvantages. This point will be carefully observed. Each year part of the original 500 head will be replaced by selected heifers, with the idea of building up the grade of the herd. The cows taken out and the surplus of heifers from the increase will be used to replace less desirable breeding animals in the main herd of the Reserve.

## PREVENTION OF LOSS.

All things considered, the biggest hazard of the stock industry on the desert and semidesert ranges of the Southwest is the occurrence of heavy losses during years when there is little or no rainfall. In the past such losses often have wiped out in one season the accumulated profits of years. The southwestern range stockman is confronted constantly with the possibility that next year may be a bad one.

### HOLDING RANGE FORAGE FOR USE DURING CRITICAL SPRING MONTHS.

In average years the most dangerous period is from February to the beginning of the summer rains, usually in July. When no rains come and the dry period extends throughout the year, the situation is critical. The first step in providing for both the average and the emergency year should be to save a good portion of the grama-grass range for use from February to July. Some range must be available for this period, and it is economy to hold the grama grass, since it retains its feeding value better than other range.

This practice has worked well at the Jornada Range Reserve. Pasture 10, of 12,293 acres, mainly grama grass, is reserved largely for the 500-head breeding herd from November or December until green feed comes the following year on the summer range. This means that the bulk of the feed of Pasture 10 is available for the critical part of the year. Pasture 2, of 34,545 acres, mostly grama grass, is grazed lightly during the growing season, mainly by steers and by breeding cows which need extra care during winter and spring. About 250 thin cows and their calves from the main breeding herd were carried through the critical dry period of spring and summer in 1916 by the dry grama grass reserved in Pasture 2. Without this feed a number of them would undoubtedly have died. The special breeding herd of 500 was held mainly in Pasture 10 until July. Loss from starvation was prevented by supplementing the dry grama grass with a small quantity of cottonseed cake.

In order to have additional range for the breeding stock in especially critical years, about one-third of the carrying capacity of the Reserve in average years is used for steers. In good years the steer stock can be increased as a means of completely utilizing the forage and in bad years, if necessary, part or all of the steers can be sold, thus releasing one-third more range for the breeding stock. There is usually a ready market during the spring and summer for steers for shipment to northern ranges, so that sales can be made without any great sacrifice. In addition to preventing loss, this plan makes it possible to build up the breeding stock without interference from forced sales of female stock.

This plan worked well in 1916. Range conditions were observed carefully during the dry spring, and on May 1 1,573 head of steers were sold. In average years they would have been replaced by purchase of yearling steers, but owing to the unfavorable season this was not done. The extra feed was held for the breeding stock.

## CONCENTRATED FEED (COTTONSEED CAKE) TO SUPPLEMENT RANGE FORAGE.

Although the plan of reserving range feed and, when necessary, reducing the number of steers by sale will aid a good deal in reducing the loss from starvation; it will not do away with it altogether, nor will it prevent the breeding stock from getting too thin, nor insure that the growth of calves and young stock will not be retarded greatly. It will be necessary, even in average years, to supplement the range forage with some concentrated feed, such as cottonseed cake. The percentage of the stock which will need feed and the period of feeding will depend largely upon the year.

F-32470A

YOUNG BULLS FOR USE ON THE JORNADA RANGE RESERVE.

These registered bulls were bought at the Kansas Hereford Breeders' Association sale in November, 1916.

F-25728A

MAKING ENSILAGE OF SOAP-WEED (YUCCA) TOPS.

The heads were run through an ordinary ensilage cutter into a pit silo.

The spring and summer of 1916 were more severe than the average and, although there was a good deal of dry grama grass available up to the time the rains came, it was advisable to feed considerable cake, mainly to breeding cows, weaned calves, and bulls.

A total of 25,650 pounds of cake was fed to the special herd of 500 breeding cows and 20 bulls. About 75 per cent of the herd were "caked" at one time or another. The cake cost approximately $40 per ton, or a total of $534 at the feed yards on the Reserve. As a result of this feeding not a single animal was lost from starvation, the calves were kept growing in spite of the fact that many of them were mothered by 2-year-old heifers, and the cows and bulls were kept in fair breeding condition.

There is some question as to the advisability of feeding cake to calves weaned in the fall from the time of weaning until green grass comes. The advantages of such feeding are that it keeps the calves growing, or in condition to make rapid growth when green feed comes; that it prevents loss from starvation; and that it makes it possible to take the calves from thin cows at an earlier age than is advisable where the calves must winter on dry range alone. These considerations are important, but it is difficult to measure them in dollars and cents for comparison with costs. Observations over several seasons, however, indicate that such feeding pays.

During the fall and winter of 1915–16 about 700 head of weaned calves were fed on cake to supplement the range feed. The quantity of feed used and costs were as follows:

| | |
|---|---|
| 37.2 tons cottonseed cake at $36 per ton at railroad | $1,361.50 |
| Hauling cottonseed cake to Reserve from railroad at $3 per ton | 111.60 |
| 145 bales alfalfa hay | 72.50 |
| Hauling alfalfa hay to the Reserve | 9.00 |
| Labor and board for feeding, 6 months at $40 per month | 240.00 |
| | 1,794.60 |
| Average cost per head for 700 head | 2.56 |

The alfalfa hay was used in mixture with the cake until the calves learned to eat the cake alone. The average feed of cake was 1.8 pounds.

The value of keeping the calves growing is apparent in the sales of steers. From the 700 head caked, 100 head of long yearlings were cut out and placed with the 2-year-old steers for sale May 1, 1916. The steers were sold by the head, with the privilege of a 10 per cent cut. When the cut was made, 101 of the older steers were cut back and finally sold at $10 per head less than the sale price for the herd. Not one of the caked yearlings was included in the cut. The 2-year-olds cut back had not been caked as calves following weaning. The remainder of the steer calves fed during the winter of 1915–16 were held on the Reserve during the summer and winter and were sold for May delivery, 1917, at from $2 to $2.50 per head more than was paid by the same buyer for other steers of the same age in the vicinity of the Reserve.

It would seem, therefore, that the increased value of the calves as a result of caking more than paid for the cost of feed and feeding, to say nothing of the small loss of calves and the advantage to thin cows in having their calves weaned early. The total loss of calves and yearlings from starvation on the Reserve during 1916 was three head, two of which were "dogie" calves not fed, and the third apparently died of starvation in the pastures through failure to come in to feed and water. Up to April 1, 1917, equally good results have been secured in eliminating loss from starvation.

### PROVIDING ROUGHAGE.

The feeding of cottonseed cake does not do away with the necessity for roughage, either in the form of range forage or in some other form. The dry cured forage on the range will usually meet this need, but in case of prolonged drought, such as occasionally comes in the southwest, the supply of range feed may become exhausted. To meet such emergencies, it would be a distinct advantage to accumulate a reserve supply of roughage in the form of hay or ensilage during the more favorable years.

With this in view, two pit silos, lined with cement, were constructed in 1915. In August, one of about 20 tons' capacity was filled with tobosa grass and a small quantity of soap weed. The tobosa grass was cut just before it matured and was run through an ensilage machine into the silo. Late in the winter of 1916 the silo was opened and the ensilage fed to 2-year-old steers and milk cows. Even though the stock were thin, they refused to eat the ensilage to any extent. A small quantity of tobosa grass was cut and put up as hay. This also the stock refused to eat unless starved to it. It is doubtful if tobosa grass will be of any real economic value, either as hay or ensilage.

The other silo has a capacity of about 200 tons. In early December, 1915, about 150 tons of soap weed (*Yucca elata*) was gathered and run through an ensilage cutter into this silo. The top was covered with straw and earth and left closed until March, 1916. The silo was then opened, and a few poor cows were fed a ration of the soapweed ensilage once a day. Most of them learned to eat it quickly and with relish. About 10 tons of the ensilage was fed with encouraging results. The pit was then closed; it will be opened later, when there is need of supplemental feed.

During the short interval between filling and opening the silo the coarse fiber of the soap-weed leaves had softened a good deal; but it was still rather tough, and the stock had difficulty in eating it. This was due, in large part, to the fact that the ensilage machine used would not chop the thick, tough leaves fine enough. Portions 6 inches long were not uncommon. A machine which would chop the leaves into smaller pieces would improve the ensilage a good deal.

The soap weed can be cut, hauled, and put into the silo at a cost of $2 to $2.50 per ton, not including cost of the silo. It takes two or more years after the first cutting for the plants to produce a growth of leaves large enough for a second. It would not be practicable therefore to fill a silo each year in the same place. This, of course, is something of a disadvantage.

Though the test has just begun, it seems probable that soap weed may prove of considerable value as ensilage. Further tests will be made to determine feeding value and secure more complete data on costs and returns.

### PREVENTION OF BLACKLEG.

During the month of May, 1915, more than 50 head of young steers out of approximately 1,000 head in one pasture of the Reserve died of blackleg. Prior to this time losses were rather heavy among the weaned calves. A campaign for systematic vaccination of all stock between the ages of approximately 5 months and 20 months was started in the fall of 1915 and has been continued to date.

The vaccination is done, for the most part, during the fall round-up and again during the early spring. The idea is to vaccinate twice a year as a preventive of blackleg, not as a cure. About 2,500 doses of the Government blackleg vaccine were administered during 1916. The vaccine was prepared carefully and administered carefully and every reasonable precaution taken to insure thoroughness. The area is large, however, and it is next to impossible to get all the animals for vaccination at the proper time. Consequently a small loss is expected. The test, however, is a demonstration of what can be accomplished under range conditions on a large scale.

A loss of 27 head during 1916 was attributed to blackleg; but in the case of at least three of these there was some doubt as to the cause of death, since the animals were not found until several days afterwards. This means a loss for the year of approximately 1 per cent of the average number of stock between the ages of 5 and 20 months, but less than 1 per cent of the total stock of susceptible age. On the basis of the average number of stock on the Reserve during the year, it is equivalent to a loss of a little over one-half of 1 per cent. One stockman on range adjoining the Reserve reported a loss of 100 head from blackleg during the first half of 1916 from approximately the same number of stock as are on the Reserve.

### TOTAL LOSS.

The total losses on the Reserve from June 1, 1915, the time that the department representatives began an active part in the campaign against loss, until December 31, 1916, was 54 head of all classes, or at the rate of 1.9 per cent annually. The total losses from January 1, 1916, to December 31, 1916, were 66 head, or 1.5 per cent. The 1916 losses included 13 cows, 2 bulls, 35 yearlings, 4 branded calves, and 12 unbranded calves. Possibly a few head were missed, so that the total might be slightly higher, but not appreciably so.

Reports received from stockmen in connection with the investigation of live-stock production on western ranges in 1914 showed average losses for New Mexico as follows: Calves up to 12 months of age, 10.6 per cent; yearlings, 5.6 per cent; stock over 2 years old, 5.8 per cent. If these figures are approximately correct, and it is believed that they are, the small losses at the Jornada Range Reserve since June 1, 1915, show decidedly encouraging possibilities for reducing losses from starvation, blackleg, straying, and other causes. Records for a period of years will be necessary for comparison with the figures cited for New Mexico as a whole. The results at the Reserve to date, however, justify serious consideration by stockmen. Systematic vaccination is possible under range conditions. It should be done as a preventive, and not as a cure after the disease is prevalent in a herd. Much can be accomplished also in preventing loss from starvation, even on the open range, though it can not be handled with the same efficiency as on fenced areas.

## CONCLUSIONS.

### RANGE IMPROVEMENT BY NATURAL REVEGETATION.

Primarily as a result of (1) reducing the number of stock during the main growing season of about four months—July to October—to about half the average number the area will carry for the year, (2) not overstocking during the other eight months, and (3) better distribution of stock watering places, grama-grass range on the Jornada Range Reserve has improved in three years at least 50 per cent, as compared with similar adjoining unfenced range grazed yearlong. Observations to date indicate that range thus lightly grazed during the main growing season has improved approximately to the same extent as similar range protected from grazing the entire year.

On fenced grama-grass ranges of the Southwest where the stock are carried mainly on range feed throughout the year, light stocking during the growing season is profitable. It will probably not reduce the total animal-days' feed furnished on a given area during the year, and will reserve feed for the critical period from February to July, or later in case of prolonged drought.

Where the whole of a range unit is made up of grama or similar grass, about one-third of the area should probably be reserved for light grazing during the growing season two years in succession. Each third in turn should be given as nearly as practicable this amount of protection. By light grazing is meant grazing by not more than half the average number of stock that the area will carry for the year as a whole.

### WATER DEVELOPMENT.

Fairly efficient use of plains and mesa range in the Southwest can be secured where stock do not have to travel more than 2½ miles to water. This means one watering place for each 13,200 acres. Such an acreage of grama-grass range will carry about 500 cattle throughout the year if properly managed.

As the distance in excess of 2½ miles which stock have to travel to water increases, the barren area around water increases, as does also the partly used forage beyond 2½ miles from water. Consequently the number of stock the range will support is reduced. When feed is short, a long distance between feed and water tends to increase the loss of stock, to decrease the calf crop, and to retard development of the young animals.

Observations to date appear to justify one permanent watering place for each 500 head of cattle. Where conditions are favorable, the construction of tanks to catch flood waters for the purpose of supplementing the permanent watering places will be a paying investment. They will aid (1) in getting more green feed for the stock during the year, (2) in more even utilization of the range as a whole, (3) in the protection of feed and range near permanent water, and (4) in reducing the cost of maintenance and operation of wells.

### CARRYING CAPACITY.

During 1916 the Jornada Range Reserve as a whole supported one animal, not including unweaned calves, on an average of 41.45 acres. The estimated maximum carrying capacity of the Reserve in its present stage of development is 38.1 acres per head. The estimated carrying capacity of similar unfenced range in its present average condition is at least 50 acres per head.

The range on the plains, where grama grasses form the bulk of the forage, will support stock throughout the year at the average rate of one head to from 20 to 30 acres, depending upon the proportion of the real grama-grass type. This figure is for range in good condition, fairly well supplied with stock water, and which is lightly stocked during the growing season.

The range comprising tobosa-grass flats, along drainage lines, and slopes back to the foothills will support stock throughout the year at the average rate of one head to from 38 to 45 acres, depending upon the percentage of tobosa flats which receive flood water. Such areas are of higher forage value than the average for this class of range as a whole.

The mountain range of the Jornada Range Reserve will support stock at the rate of approximately 60 acres per head in its present stage of development.

All of the foregoing estimates are on the basis of carrying the stock through average or slightly less than average years in fairly good condition. If loss from starvation is to be eliminated, a small percentage of the poor stock will have to be fed cottonseed cake or other feed to supplement range forage.

### INCREASE IN CALF CROP AND IMPROVEMENT IN GRADE OF STOCK.

From 500 selected cows and 20 bulls, held in pastures away from other stock since August, 1915, an 81 per cent calf crop was branded in 1916. It is expected that this figure will probably be an average one over a period of years. From the remaining cows of breeding age, amounting to 1,522 head run together in one pasture of 74,714 acres, a 69.2 per cent calf crop was branded. The average calf crop for the Reserve was 72 per cent. It is doubtful whether the average calf crop on adjoining unfenced range in 1916 reached 60 per cent, and this figure is believed to be a high average for the calf crop on these ranges for a period of years past.

A total of approximately 50 pounds of cottonseed cake per head was fed to the 500 cows and 20 bulls of the selected breeding herd on the Reserve. The work of caring for this herd took half of one man's time. All of the bulls and perhaps 75 per cent of the cows were fed cake. To this special care and the fact that they were unmolested by other stock is attributed the large calf crop. In the herd having 1,522 head only 2 per cent of the cows and only 75 per cent of the bulls were caked. This and the fact that so many animals were run in one large brushy area, making adequate bull service difficult, are believed to be largely responsible for the difference of 11.8 per cent in the calf crop of the two herds. If so, the extra calves in the special herd far more than pay for the extra feed and labor.

The big opportunity for increasing the calf crop is to keep poor cows in thrifty condition. This can be done by not overstocking the range used by breeding stock and by feeding a small quantity of cottonseed cake or other supplemental feed to the cows that need it. Indications are that this is a good business proposition. All bulls should be fed during the winter and early spring.

By avoiding overstocking and by using supplemental feed the improvement of the average animal should pay, at least in part, for the decrease in number of stock and increase in cost of care. The increase in the calf crop will pay for the greater part, if not all, of the increased expense. Marked improvement in average grade is noticeable among stock of the Jornada Reserve as a result of selling off about 25 per cent of the poor-grade, off-colored, and otherwise undesirable stock, and replacing them by good grade heifers.

### PREVENTION OF LOSS.

The average loss of stock on the Jornada Range Reserve, June 1 to December 31, 1915, was at the rate of 1.9 per cent for a year; the average loss in 1916 was 1.5 per cent. The average losses for New Mexico are approximately 10.6 per cent for calves to 12 months of age, 5.6 per cent for yearlings, and 5.8 per cent for other stock.

The small loss at the Jornada Reserve is attributed to careful, systematic vaccination against blackleg, to the reservation of grama-grass range for poor stock during the critical spring months, to feeding the animals a small quantity of cottonseed cake, and to prevention of straying.

In order to provide for extra range for the breeding stock in poor years, one-third of the stock on a range unit should be steers. It is then possible to reduce the number of stock, when necessary, by selling steers, without great sacrifice and without interfering with the breeding stock. In good years the number of steers can be increased and in bad years decreased.

To provide against loss in extremely bad years, some kind of roughage to supplement the range forage, for feeding with cottonseed cake or other concentrated feed, would be a decided advantage on southwestern ranges. Ensilage made from soap weed (*Yucca elata*) has been tried, and the results are promising, but not extensive enough to warrant definite conclusions.

Feeding cottonseed cake to calves weaned during the late fall, winter, and early spring is an important factor in cutting down loss and increasing the size of the stock, as well as in increasing the calf crop. Where this is done, young calves can be taken from poor cows, thus reducing loss from starvation among both cows and calves and stimulating earlier breeding. Indications are that such feeding is a good business venture from the standpoint of increased value of the calves, aside from decreasing the loss from starvation.

Range feed not more than 2½ miles from water is a big factor in cutting down loss from starvation, especially where little or no supplemental feeding is done.

The possibilities of decreasing loss justify more attention on the part of stockmen to careful, systematic vaccination as a preventive of blackleg and to picking out and feeding stock in need of special care.

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UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 589**

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

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# THE 28-HOUR LAW REGULATING THE INTERSTATE TRANSPORTATION OF LIVE STOCK: ITS PURPOSE, REQUIREMENTS, AND ENFORCEMENT.[1]

By HARRY GODING and A. JOSEPH RAUB,
*Bureau of Animal Industry.*

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## ENACTMENT OF THE LAW.

During the Forty-second Congress a law was passed to prevent cruelty to animals while in the course of interstate transportation, which was approved by the President on March 3, 1873, and incorporated in the Revised Statutes of the United States, first edition, as sections 4386 to 4390, inclusive. This law was enacted to prevent any carrier from transporting animals in interstate commerce for a longer period than 28 consecutive hours without unloading for the purpose of rest, water, and feeding for at least 5 consecutive hours before continuing their transportation. If, however, the animals were carried in cars, boats, or other vessels in which they could and did receive proper food, water, and rest, the statute permitted the carrier to transport them without unloading.

To comply with the act, it became necessary for the transportation companies to provide feeding, watering, and resting facilities at convenient places on their lines, separated in distance according to running schedules, so as to be able to unload the stock each 28 hours during their journey to destination. In the construction of the inclosures or pens into which the animals were to be unloaded little if any consideration was given to the habits, requirements, and comfort of the different classes of animals handled. So long as the pens were inclosed by a fence and the animals were unloaded within the 28 hours, the transportation companies considered that they had complied with the law. Fences of sufficient height and strength to restrain the animals were not provided in many cases, and a round-up of cattle which had either broken down or jumped over such fences was necessary before reloading could be commenced. Watering troughs often were not provided, and the absence of feeding racks was very general. No thought whatever was given to the comfort of the animals in the way of providing a dry place to lie down for rest.

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[1] The authors acknowledge the cooperation in this work of Mr. J. V. De Laney, who at the time was in the service of the Bureau of Animal Industry.

On account of the poorly constructed pens and inadequate resting, watering, and feeding facilities and the frequent unloading of the animals, considerable dissatisfaction arose among the shippers. This, together with the changes in the way of improved railroad transportation and the increasing size and importance of some of the live-stock markets, led to the repeal of the act of 1873 and the enactment of the present law, commonly know as the 28-hour law, which was approved and became effective on June 29, 1906, and was committed to the Secretary of Agriculture for enforcement. The new law corrected some of the defects of the act of 1873 and made possible the elimination of some of the abuses practiced under that statute.

## PURPOSE OF THE LAW.

While the 28-hour law was enacted primarily for humane reasons, to reduce to a minimum the cruelty incident to the transportation of live stock, it also protects the interests of owners of animals and of the public, in preventing the health and condition of the animals from being injured while in transit. To have his stock reach the market in as nearly the same condition as when it leaves the farm or the ranch is the object of every stockman and shipper. This can be accomplished only by giving the animals while they are in transit the care, attention, feed, water, and rest to which they have been accustomed, or as nearly so as possible. If animals are confined in cars for an excessive period without feed, water, or rest, or if after being confined in the cars for a period of 28 or 36 hours they are unloaded into a pen too small for them to rest or even move about, or too muddy to lie down, or if the proper kind and amount of feed and water are not supplied, or if in the unloading or reloading process the animals are beaten, thrown from the cars, or otherwise brutally treated, the object desired by the shippers and intended by the law is not attained. The live stock as the result of such treatment arrive at destination in a feverish condition and the quality of the meat may be affected if the animals are slaughtered while in that state.

The main purpose of the statute, however, is to prevent cruelty to animals while in the course of transportation. How well it has served this purpose may be judged from the fact that whereas formerly it was not uncommon for carriers to confine animals in cars for periods of 50 to 60 hours or even more, now the carriers, as a whole, are endeavoring to unload them within the statutory period and to give them proper care and treatment when unloaded.

## REQUIREMENTS OF THE LAW.

### PROPER FEED AND WATER.

The statute requires that the animals while in the course of interstate transportation shall be provided with proper feed and water at the expiration of each period of 28 hours unless the owner or person in custody of the live stock has authorized their confinement in the cars for an additional 8 hours, in which event it is required that the animals be furnished with proper feed and water at the end of every 36 hours by the shipper, but if he fails to meet this requirement, the transportation company must do it for him. This additional 8 hours of authorized confinement is one of the provisions in the law of 1906 which did not appear in the law of 1873, and enables the shipper to get his live stock to market in many instances without the necessity for unloading the animals, avoiding the delay, inconvenience, and feeding expense incident thereto. The majority of shippers avail themselves of this privilege. There are, however, some serious abuses practiced in this connection which are mentioned later.

By proper feed and water is meant not only sufficient feed to allay hunger and sufficient water to quench thirst, but the feed and water must be of a proper quality and must be furnished at proper intervals. It is not required that feed be furnished in quantity large enough for fattening, but enough to satisfy hunger and thereby keep the animals quiet and contented during their journey to destination.

The amount of feed which should be given to various classes of animals varies with the length of time between feedings and the weights of the animals. It is believed that for each 24 hours the ration for horses and cattle should be not less than 1¼ pounds of hay to each hundredweight of animal; for sheep, not less than 1½ pounds of hay to each hundredweight of animal; and for hogs, not less than 1 pound of shelled corn, or its equivalent in ear corn or other grain, to each hundredweight of animal.

When animals are transported in "palace" or similar stock cars or with emigrant outfits, or in specially equipped cars conveying show animals and blooded stock in which they can and do have proper feed, water, space, and opportunity to rest, the provisions in regard to their being unloaded do not apply. However, in cases where animals are fed in the cars care should be exercised to distribute properly through each car sufficient feed for each animal, so that none will be deprived of the opportunity to get its share.

In the watering of the animals the water in all cases should be clean. As a general rule, live stock will not drink dirty or polluted water. Where the watering is done in the cars it is necessary that the troughs be thoroughly cleaned out before the water is turned into them, and each animal should be allowed to drink its fill. While the watering of live stock in the cars has been found to be rather unsatisfactory, if the watering is to be done in this manner the troughs should be large and deep enough so that the water will not run out, and they should be so constructed as to be readily placed in operation and yet so arranged that the animals can not tilt them over. They should also be so placed in the cars that all the animals can get to them. It is not a compliance with the law to water the animals on one side of the car, while those on the other side receive no water whatever, or an insufficient quantity.

### SUFFICIENT REST.

It is permitted by the law to transport animals without unloading, provided they are carried in cars in which they can and do have proper feed and water and in which sufficient space is provided for all the animals to lie down at the same time. If all of these conditions are not met, the law requires that the animals be unloaded at the expiration of a period of 28 hours, or, if a request has been signed by the owner or person in custody of the live stock, at the expiration of a period of 36 hours. Railroad regulations establish a minimum weight of carload lots for various kinds of animals. In order that a shipper may benefit by this, it often is necessary for him to overload the car as regards space, especially in the case of long-wooled sheep, canner cows, feeder cattle, and mixed lots of animals. In such cases it will readily be seen that the stock do not and can not have sufficient space for all to lie down at one time. Under such conditions it is a very common occurrence to find one or more animals either crippled or trampled to death on account of being unable to rise after having lain down to rest.

When unloaded, it is required that the animals have at least 5 consecutive hours of rest. The conditions must be such that animals can rest properly. It is obvious that when animals are placed in yards filled with mud, water, snow, or slush, or which are not provided with a proper shelter from rain, snow, wind, and sun, they can not obtain rest, for, as a general rule, they will not lie down in such surroundings.

### HUMANE HANDLING.

The law is a humane measure, intended not only to prevent the carrier from transporting animals in interstate commerce for long periods, but also to provide that they be unloaded in a humane manner into properly equipped pens for rest, water, and feeding. The cruel treatment of animals in the past in their handling and care while in transportation not only reduced their food value, but led to numerous claims against the railroad companies and finally to the enactment of the present law. Many instances have been observed in which the most brutal treatment has been given to the animals, resulting many times in severely injuring them. There have even been cases where hogs and sheep were crippled purposely by the persons unloading the animals, for the financial betterment of their employers. The provision as to humane handling of the animals was added to the requirements when the law of 1906 was passed, no such requirement appearing in the prior statute. The handling of live stock in a humane manner protects not only the animals, but the interests of the owners and of the public, because it helps in placing the stock upon the market in good condition; it incidentally benefits the carrier as well.

### PROPERLY EQUIPPED PENS.

The law of 1906 requires that animals shall be unloaded into properly equipped pens for rest, water, and feeding. While the statute does not require a carrier to maintain any particular kind of equipment of its stock pens, permanent or otherwise, except in so far as to render them suitable for the humane purpose of the act, it is necessary to make such provision as will meet the weather conditions of the different seasons of the year, so as to provide for the protection of the animals from the elements. In erecting such pens consideration should be given to the kind of animals to be handled; the feeding, watering, and resting facilities; drainage; weather protection, and lighting for night handling. In the winter time, particularly in the northern parts of the country, protection from cold, storms, snow, sleet, and winds must be provided. For this purpose a portion, at least, of the yards should be covered. It will also be necessary to have some such provision made for the protection of the animals from the hot sun in the summer time, particularly in the Southern States.

The yards should be so equipped that it will not be necessary to feed and water hogs and other animals, especially horses or sheep, from the same troughs, as other animals will not eat or drink from troughs which are also used for hogs. The feeding of hay to cattle or other stock on the ground might enable the carrier to comply with the law where the ground is dry; but in open pens when it rains or snows the ground becomes muddy, and the animals will trample the feed into the mud and then refuse to eat it. Pens into which hogs are unloaded should have a floor of some hard substance, on account of the tendency of hogs to root. During cold weather, also, hogs will make depressions in unpaved pens and then lie down in them, piling one on another to keep warm. In this way some hogs are smothered.

In constructing a properly equipped feeding yard the floor space, including pens and alleys, should be filled in with cinders or other suitable material and allowed to settle, then paved with rough brick or roughened concrete, and properly sloped for drainage. A portion of the yards should be covered and boarded up on the north and west sides and so arranged that at least a 2½-foot space just above the level of the yard fence can be opened during warm weather to allow a good circulation of air. (See fig. 5.)

All pens should be equipped with watering and feeding facilities for the particular kind of animals to be handled, and no yard should have less than 50 feet of feeding-rack space and 15 feet of watering trough. Yards in which double decks of sheep are yarded should have between 80 and 100 feet of feeding-rack space. Water troughs of sufficient size (approximately 15 feet long, 12 inches deep, and 12 to 15 inches wide for each single-deck yard) to allow the animals to get their fill within a short time should be provided, and each trough should be drained directly from the plug to the sewer, which will allow the water to drain from the troughs, thereby avoiding freezing in the winter and stagnant water in the summer. Each trough should be provided with a separate shut-off for the water, and the hydrant boxes should be packed properly during the winter to avoid freezing. As before indicated, yards that are used for both hogs and other animals should be equipped with two sets of watering troughs. Feeding racks built with boards running parallel with the length of the rack at which sheep are fed should have a space of at least 7½ inches between the boards, about 18 to 20 inches from the floor, which will allow the heads of the sheep free access into the rack and out again while feeding. Vertical slats of round iron should be about 7½ inches apart in order that the sheep may get at the hay readily. Sufficient lighting facilities should be installed for loading and unloading during the night; an example of this is seen in Plate I, figure 1.

Loading and unloading chutes and docks should be built to acommodate the kind of animals handled. Figure 1 illustrates a good arrangement for unloading double-deck cars.

Fences for the yards should be of sufficient height and strength to restrain the animals properly. The yards should be drained properly by a sewerage system of some kind, and each yard should be sloped toward the sewer connection. Each trough also should have a separate sewer connection. In providing unloading chutes for horses care should be taken to avoid sharp turns, and injury while loading and unloading can be averted by having the yards connected with an alley leading directly to the unloading chute.

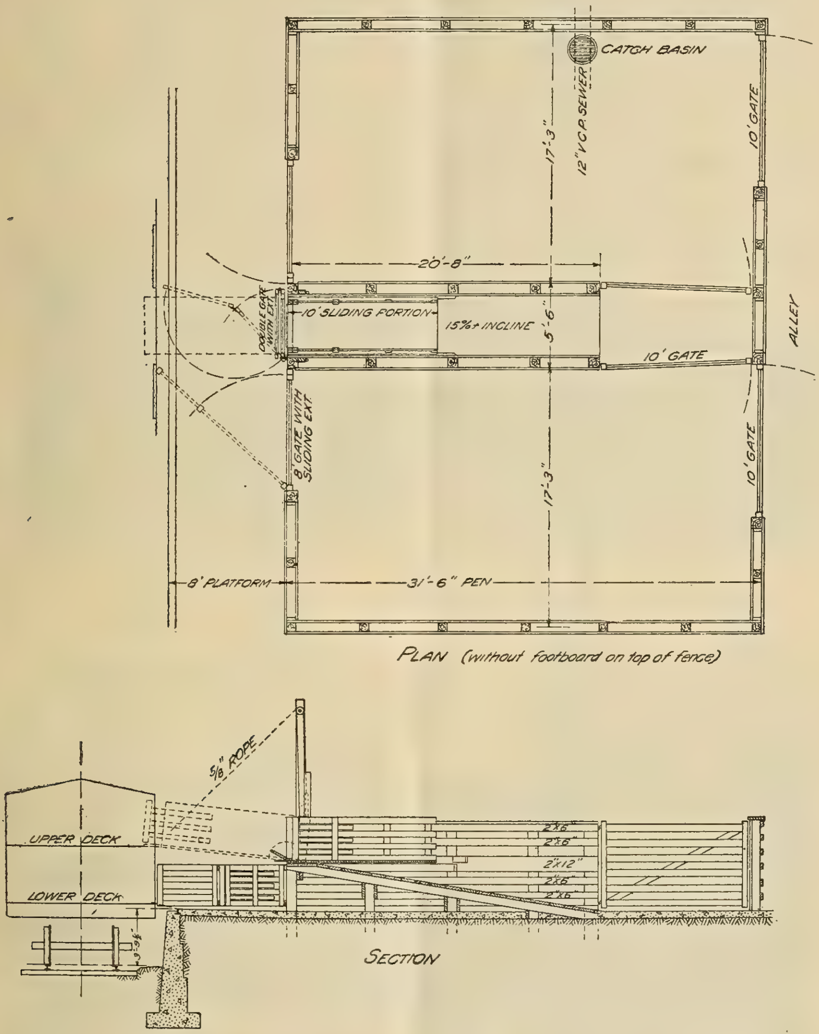


FIG. 1.—A good arrangement for unloading double-deck cars.

In size a single yard should measure approximately 25 by 40 feet, with the gate connecting with the alley placed near the corner of the yard. The alley should be about 10 feet wide, which should be the

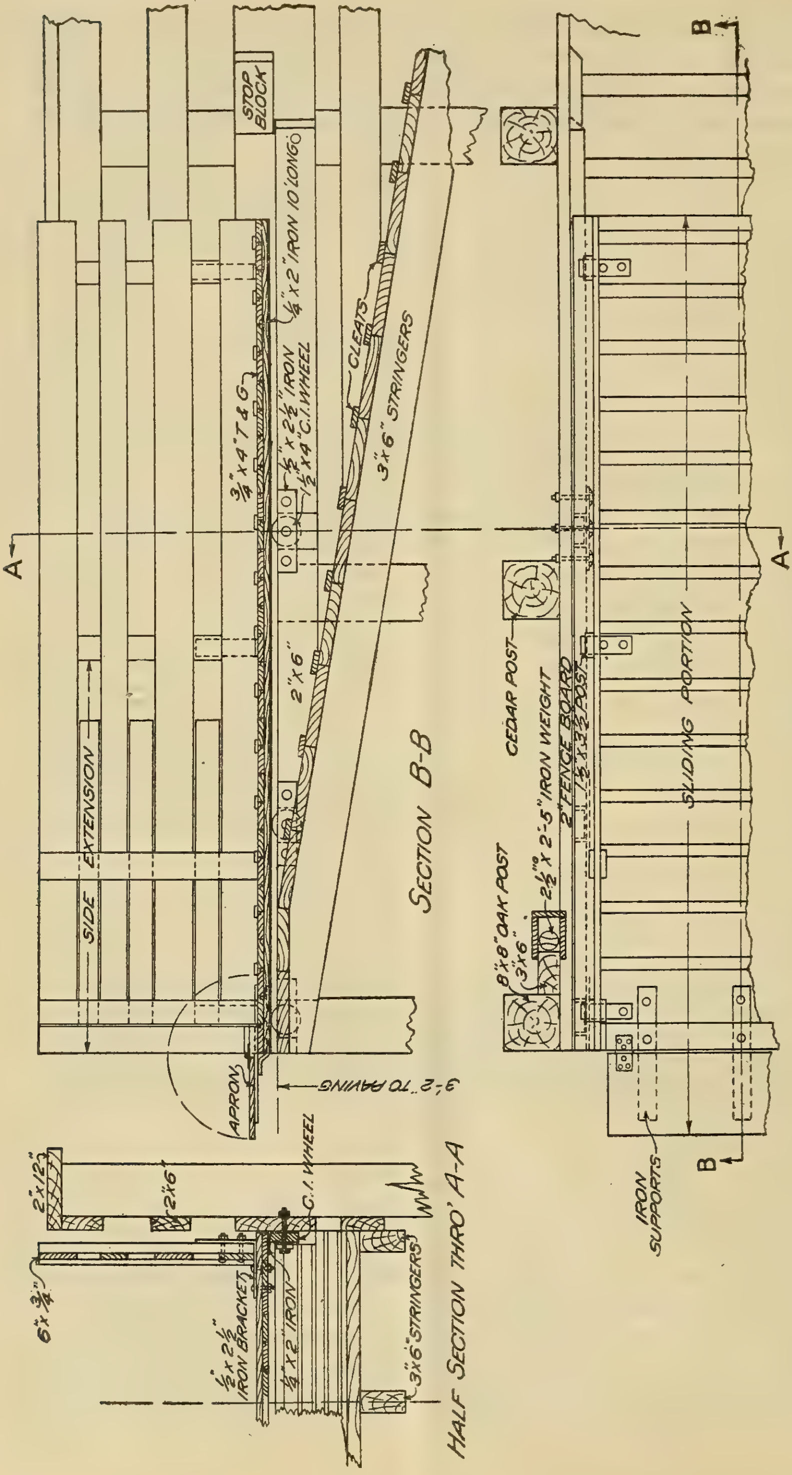


FIG. 2.—Cross section of good unloading chute for double-deck cars.

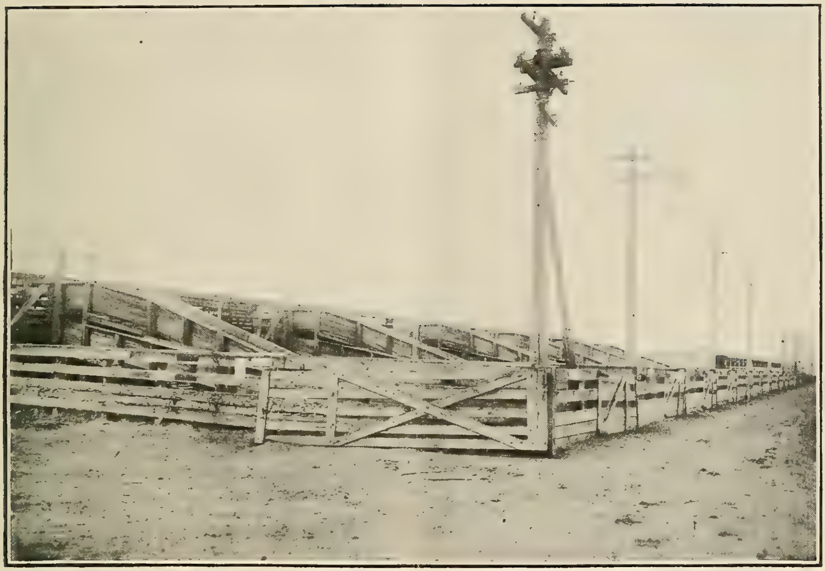


FIG. 1.—STOCK PENS WITH GOOD LIGHTING ARRANGEMENTS.

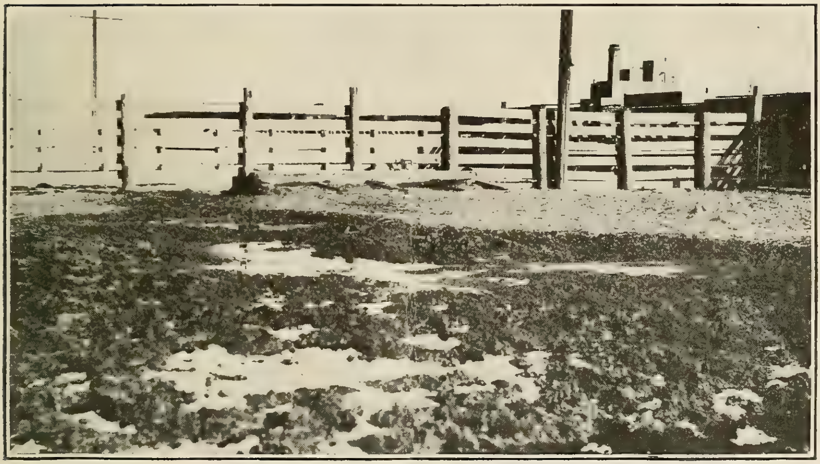


FIG. 2.—A POORLY EQUIPPED YARD.

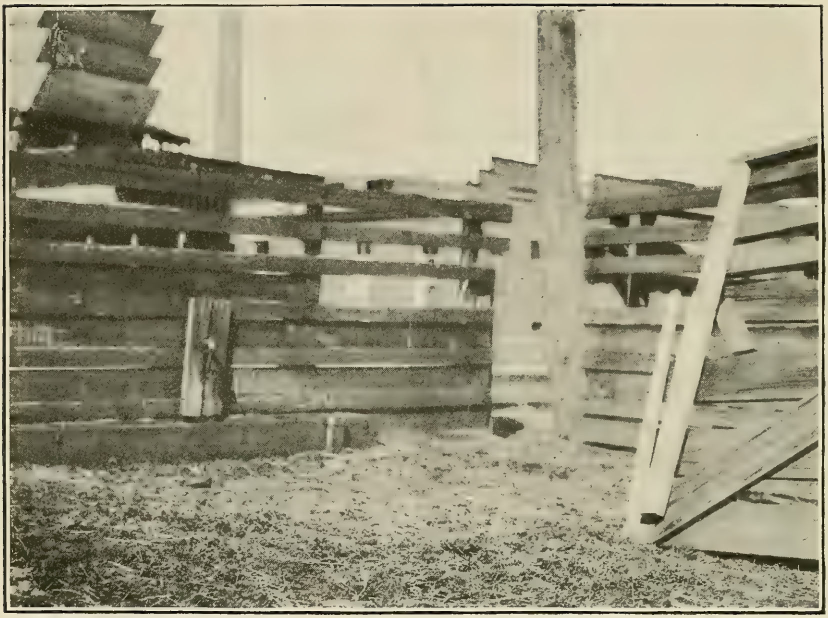


FIG. 1.—POORLY EQUIPPED YARD WITH DILAPIDATED GATE.

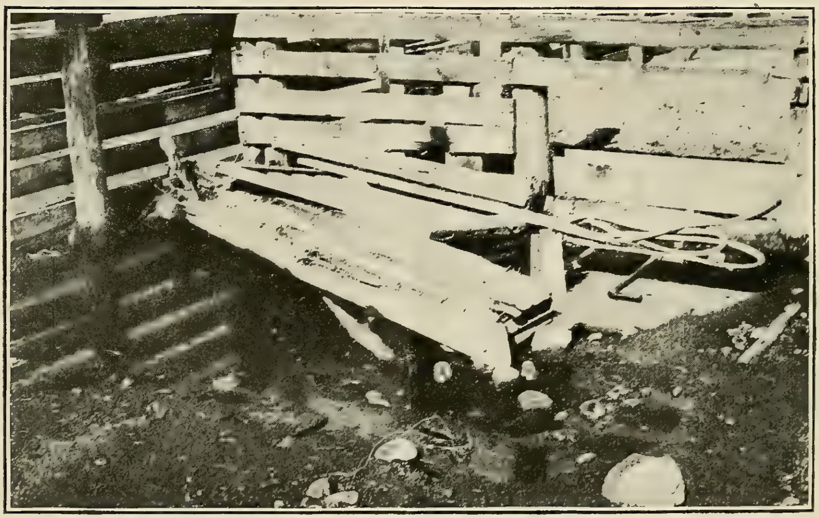


FIG. 2.—SECTION OF PEN SHOWING POOR WATERING FACILITIES.

widths of the yard gates also. The accompanying illustrations (figs. 3, 4, 5, and 6) show some of the features of a properly equipped yard or pen.

## ABUSES UNDER THE LAW.

In their attempts to comply with the older statute, carriers considered apparently that it was only necessary to unload the animals every 28 hours into some sort of inclosure or pen which in many cases was not even provided with watering troughs. Under these conditions the animals were not protected from the cold winter winds or the hot sun during the summer, and were compelled to stand in mud or water or in snow and slush sometimes knee deep. Although shippers frequently complained, temporary relief only was afforded by resurfacing the yards with cinders or gravel. Little attention was paid to the quality or quantity of feed given the animals, or whether they were fed at all, the railroads asserting that it was the duty of the shipper to feed and care for the stock in transit. They overlooked the fact that if the shipper did not feed the animals it was their duty to do so. This led to the practice of

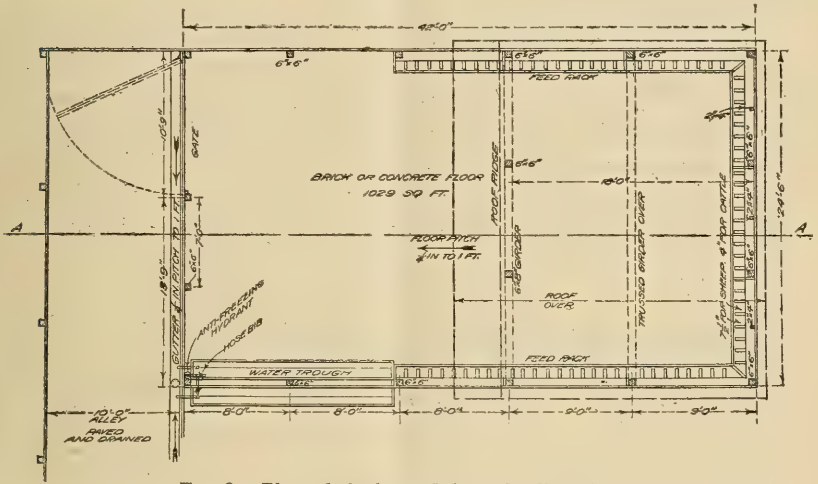


Fig. 3.—Plan of single yard for unloading stock.

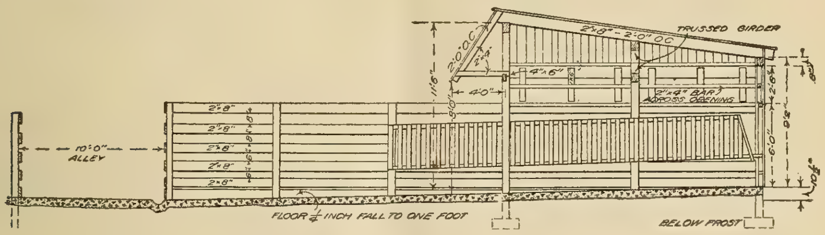


Fig. 4.—Side view of yard shown in figure 3.

individuals building and maintaining private yards where the stock was cared for at a stated cost if the shippers desired. These yards were far from perfect in equipment as well as in the service given, but in most cases they were an improvement on the old conditions provided by the railroads. This again led the carriers to think that if they conveyed the stock to such yards, no matter what the service or condition of the yards or when the animals were unloaded, their liability was ended.

Little attention was given to the class of men who handled the stock. The man who could make the most noise and wield the "prodpole" most dextrously was considered the most valuable, no thought being given to the comfort of the animals. In some yards a trough for watering all classes of animals was all that was provided, while in a great many yards no troughs were provided. In most cases it was found that one trough 14 to 16 feet long was supposed to water any amount of stock, from one car of cattle to 7,000 sheep, within the period of five hours. Often the troughs were in such condition they would not hold water, and the only way the stock could quench their thirst was by drinking from the stagnant pools or from the overflow into the mud, manure, and other filth in the corrals. Sometimes the troughs were so high that it was impossible for hogs or sheep to drink. In other cases the troughs were used as a wallow by hogs, and subsequent shipments of sheep, horses, and cattle were supposed to drink from them.

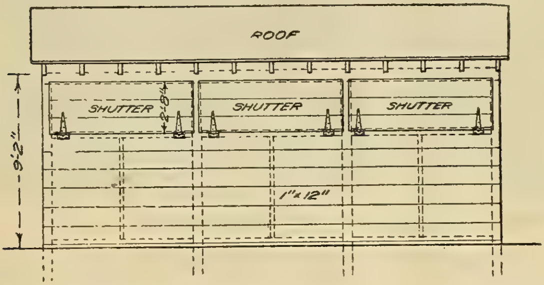
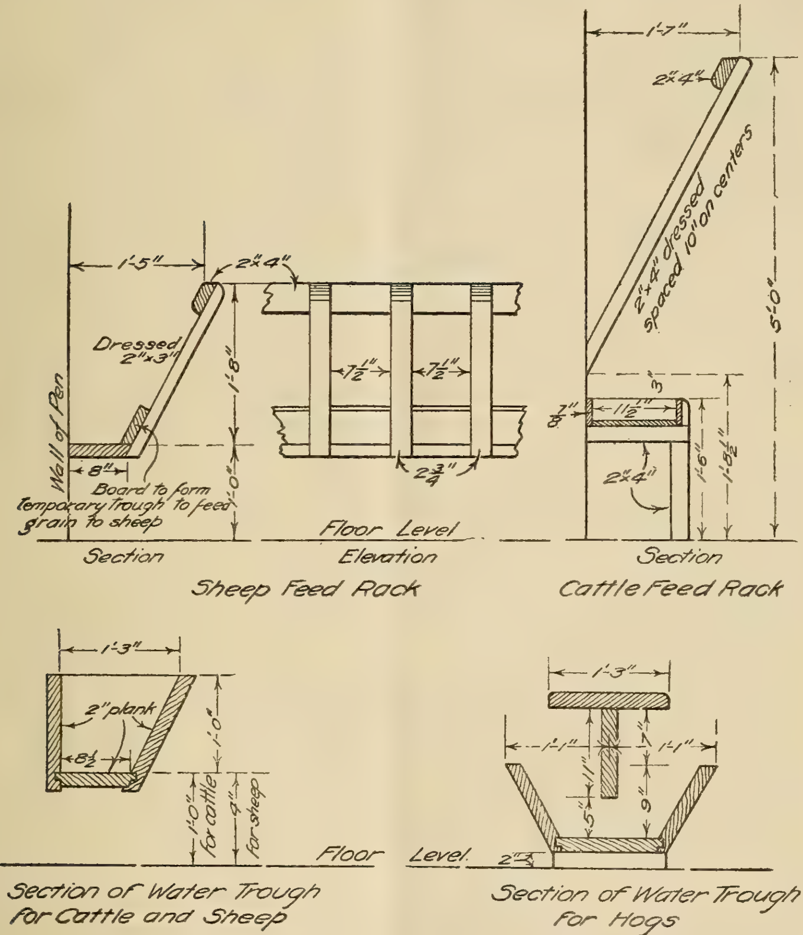


FIG. 5.—End view of covered section of yard, showing doors to be dropped for ventilation.

When a shipment of sheep or cattle has been driven several miles before loading, and perhaps confined in cars 36 hours in the summer heat, and is then subjected to the conditions described, the suffering and loss in deaths and excessive shrinkage can readily be imagined. The feeding was done in a haphazard way. No definite quantity was required for any class of animals, and often it was thrown into the mud or dirt so that little of it was eaten. Certain classes of shippers would use dry feed for at least 48 hours before reaching market centers, giving no water whatever, thinking that the stock would then drink an excessive quantity of water and that the weight would be greater than if they were watered at regular intervals. When the first cold weather came the water in the pipes at the feeding and watering stations froze, and remained so until the warm weather of the spring thawed it out. At one point the water froze in December, and although no more water was available until March, over 1,000 cars of stock were handled there and were supposed to have been watered. It was, in fact, a greater hardship to the animals to have them unloaded under such conditions as then existed than to carry them on to their destinations. The provision in the new law requiring that when live stock are unloaded it shall be into properly equipped pens has in a large measure overcome these abuses.



Section Elevation
Sheep Feed Rack

Section
Cattle Feed Rack

Section of Water Trough for Cattle and Sheep

Section of Water Trough For Hogs

FIG. 6.—Details of equipment for yard shown in figure 3.

The old law required the carriers to unload the animals at the end of every 28 hours; the present law permits the extension of the time to 36 hours upon the written request of the owner or person in custody of the shipment. This privilege generally is insisted on by the transportation companies, the argument being advanced that it enables the shipper to get his stock to market sooner, and that he is benefited through not having to pay for feeding his animals at several points in transit to market. It appears, also, that some carriers have resorted to the practice of marking their waybills to show that the confinement of the animals for a period of 36 hours has been authorized by the owner or shipper, when, as a matter of fact, such was not the case.

The law requires that the request for extension of the period of confinement from 28 to 36 hours shall be a written one. A separate request must be made for each particular shipment. This requirement was included in the law in order that the owner or shipper of live stock should exercise his own judgment as to the necessity of additional time. In other words, Congress believed that 28 hours was long enough, as a general rule, to keep live stock confined without feed, water, and rest; but the shipper or owner of the animals was allowed, if he thought it wise or to his interests, to authorize the carrier to continue the confinement of his animals for 8 hours more. Some carriers have procured such requests from the shippers upon the threat that they would unload the animals before even the 28-hour period had elapsed, unless the 36-hour requests were signed. The result of these practices is the practical abrogation of the 28-hour law and the substitution therefor of a 36-hour law.

There seems to be a belief on the part of many of the agents of the railroads that oral requests by shippers to continue their live stock in transit for 36 hours before unloading for feed, water, and rest comply with the law. This is not so, and carriers should instruct their agents accordingly. In many cases such instructions would obviate the necessity for the Government to institute prosecutions and would save the railroads from the payment of penalties for the failure on the part of their agents to secure written instead of verbal requests.

Another practice which sometimes has been followed by some of the carriers is that of placing upon the waybills and other shipping memoranda wrong notations as to the times of loading or reloading. As the various employees of the carriers along the line rely upon this information as correct, this often results in the confinement of the animals beyond the statutory period and the institution of prosecutions against the carriers for violations of the law. This is another instance in which the railroads undoubtedly could save themselves considerable money and inconvenience by issuing instructions to their employees that notations made upon the waybills or other records should be strictly correct. The Government has no alternative but to prosecute the carriers when animals are confined beyond the statutory period without feed, water, or rest owing to the carelessness, or it may be the willfulness, of some employee who placed incorrect notations upon the billing.

Another particular in which some improvement can and should be made is the handling of emigrant and express shipments. Such shipments usually originate at some small station. The person in charge of emigrant movables usually loads the stock in a corner of the car; and if they have to be unloaded, it would be necessary first to unload a part of the farm implements or household goods. In the case of crated animals the crate may be too small, but the fact that it is a crated animal seems to be sufficient excuse for the express company to take it for granted that the animal has plenty of room to lie down and rest. Fortunately, however, the greater number of express shipments are for short distances. Some of the roads now have the conductor on each division inspect such shipments to see that there is sufficient room and water and feed; and if any one element is lacking, the stock is unloaded. Some of the express companies have promised to do the same thing. If this practice is made universal, it will aid greatly in the observance of the law and will save the Government from instituting suits.

Another practice which has been resorted to by some of the carriers is the marking of their waybills so as to show that the animals had been unloaded, fed, watered, and rested, when, as a matter of fact, no feed or water was supplied, and in some instances the animals were not even taken out of the cars. This practice, it was found in some cases, was carried on without the knowledge of the higher officials of the roads and contrary to the explicit instructions of the operating officers.

## RESULTS ACCOMPLISHED.

### IMPROVED YARDS.

Since the enactment of the present law many of the railroads have improved the yards and pens into which animals are unloaded for feed, water, and rest. Some of the improvements have been installed voluntarily. Suggestions offered by the officials of the Bureau of Animal Industry as to how such yards should be constructed to meet the requirements of the law have been adopted cheerfully and gladly by some carriers. It must be said, however, that other roads have improved their yards and pens only after the Government was obliged to resort to prosecution because of the inadequate facilities provided. On the whole, the general conditions in this respect are much better than they were 10 years ago. The expenditures in this direction by some of the roads have amounted to many thousands of dollars. But this money has been well expended, as is evidenced by the fact that such roads now have comparatively few violations of the law, whereas formerly violations were numbered by the hundreds. The stockmen who ship over these roads have commented on the fact that their live stock now receive better treatment than formerly.

Formerly, in the Northwest, where the winters are longer and more severe, no shelter of consequence was provided for the animals from the cold. Repeatedly animals were frozen in the yards after unloading. When the attention of the head officials was called to such conditions and the results obtained on other lines were pointed out to them, they at once asked for advice and aid from the department, with the result that great improvements have been made at the feeding points and also in the running time of the trains. Live-stock exchanges and associations and stockmen in general have spoken in the warmest praise of these improvements. The railroads, too, have seen the big saving in losses and claims as well as in train-crew time. Yards have been paved, electric lights installed for unloading at night, sheds built for shelter, watering facilities improved, more care used in the selection of men to run the yards and handle the stock, and more attention paid to the kind and quantity of feed furnished. No yard of consequence in that section now lacks a reasonable amount of shelter for the stock and paving for at least a part of the yards, and the shipper always is assured of dry conditions no matter what the time of year may be.

Plate I, figure 2, Plate II, and Plate IV, figure 1, show some examples of poor conditions at some yards where live stock were supposed to rest, water, and feed. These photographs were taken several years ago. Plate IV, figures 2 and 3, and Plate V show yards which are regarded as proper for the feeding, watering, and resting of live stock.

### IMPROVED FEEDING AND WATERING FACILITIES.

At one of the so-called "contract feeding stations" on the line of one of the largest railroads it was customary to feed animals in the cars, particularly hogs, by throwing the feed into the cars through openings between the slats as the train moved slowly by the feed bins. This resulted in much of the feed falling to the ground, and, since the feeding was done from but one side of the train, many of the animals on the opposite side from the feeding platforms received no feed. At this place the animals were watered in the cars, but as this also was done only on one side of the train the animals on the opposite side received little if any water. This practice resulted in some of the animals being confined in the cars without any water whatever for from 60 to 72 hours, and specific cases have been disclosed in which the confinement had continued as long as 100 hours. In accordance with suggestions offered by the officials of the Bureau of Animal Industry to the higher officials of some of the roads handling live stock in this manner, the feeding and watering facilities were, at considerable cost, remodeled or rebuilt to meet the requirements of the law so that now it may be said that live stock are being fed and watered by those roads in a much more satisfactory manner than formerly. This, too, has resulted in fewer violations upon the part of those roads.

On another road pens have been provided with concrete floors and sufficient feeding space for all the animals to eat at one time. The watering troughs are ample in size and number and are constructed with sewer connections so that they can be drained easily. These pens are covered and entirely inclosed on three sides, 4 feet of the sides being equipped with drop doors so that they can be opened during the summer months for ventilation and closed during inclement weather, the roof being high enough for all classes of animals. As a general rule, however, for the entire country it is believed that yards or pens partially covered on the side exposed to the winter winds will furnish sufficient protection to the animals.

### INADEQUACY OF "FEED-AND-WATER" CARS.

The desire to get to market in as short a time as possible led some of the stockmen to prevail on the roads to build so-called "feed-and-water" cars. These cars had small metal troughs built in the sides. Hay was thrown on the floor of the car or put into overhead racks. As the cars were loaded as full as possible, it can readily be seen that the stock had no chance to rest. Often the animals were thus confined for periods of from 60 to 100 hours. It was found upon careful examination of thousands of such cars arriving at one of the largest stock markets in the East that the watering facilities of comparatively few cars were in such condition as to be of value for watering the stock. The troughs or pans were bent out of shape, broken, or rusted and full of holes so that water would not remain in them. It was also found that in many instances the chains and levers for raising and lowering the troughs were disconnected, broken, or missing entirely, and in many cases where the troughs were in working condition they were so narrow that horned cattle could not drink from them.

On account of the generally unsatisfactory results obtained by this method of watering, some of the railroads have discontinued entirely the use of "feed-and-water" cars and are unloading the animals into properly equipped pens for feed, water, and rest. The aid and cooperation of the department was asked by these roads, with the result that live-stock handling, both on the cars and at feeding points when unloaded, became more nearly ideal, and claims for losses and damages to live stock and violations of the 28-hour law were reduced about 70 per cent. Officials of one of the largest roads, which abandoned the practice of feeding and watering in the cars and built yards for the proper care of the animals, now say that they have far fewer complaints, less loss, fewer claims for damages, and less expense for train crews, as it often took several hours to set the cars so that the stock could get water in them.

It has been found also that in some cases where hogs are fed and watered in the cars the bottom of the car has been made a trough or receptacle for water. This is regarded as most unsatisfactory. Such a car is bound to have an accumulation of manure, urine, and other filth, so that instead of the animals receiving pure water they are compelled to drink a mixture containing their own excretions. Corn was then thrown into this filth. As soon as the attention of some roads was called to this insanitary method of feeding and watering animals in the cars the practice was stopped.

### BETTER LOADING AND UNLOADING FACILITIES.

At some points very poor facilities were provided for loading and unloading live stock, particularly double-deck cars of sheep. While the law provides that they shall be unloaded in a humane manner, the sheep sometimes were thrown bodily from the cars. No running board was used to unload the top deck, and the animals would either be obliged to jump a distance of several feet or land on top of those coming out of the lower deck. Dogs were put into the cars to drive out the sheep. A picture of a good loading and unloading chute is shown in Plate III, figure 1. A glance at figure 2 shows that conditions are not always the best.

The distance between the unloading platform and the car was often so great that the rush of animals, particularly cattle and sheep, in loading or unloading crowded one or more off the platform and down between the car and the dock. On numerous occasions this resulted in permanent injury to the animals, and in some cases cattle had to be killed before they could be removed.

Some roads contended that they were not required to unload sheep at night, or that it could not be done. They were informed that darkness is no excuse for not unloading within the legal limit. It has been demonstrated to them that with electric lights installed at proper places in the yards the stock could be handled in a satisfactory manner. Officials of roads which have tried this plan say that within three months after installing such lighting systems they had saved more from employees' wages, loss of stock, and damages to stock than was expended for this improvement.

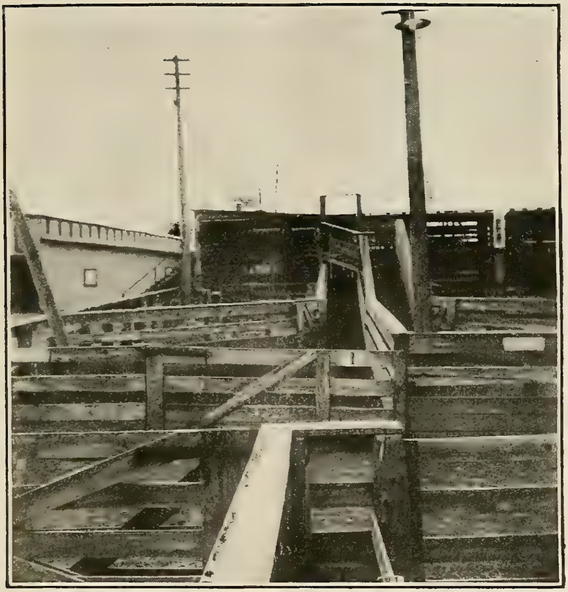


FIG. 1.—A GOOD UNLOADING CHUTE FOR DOUBLE-DECK CARS.

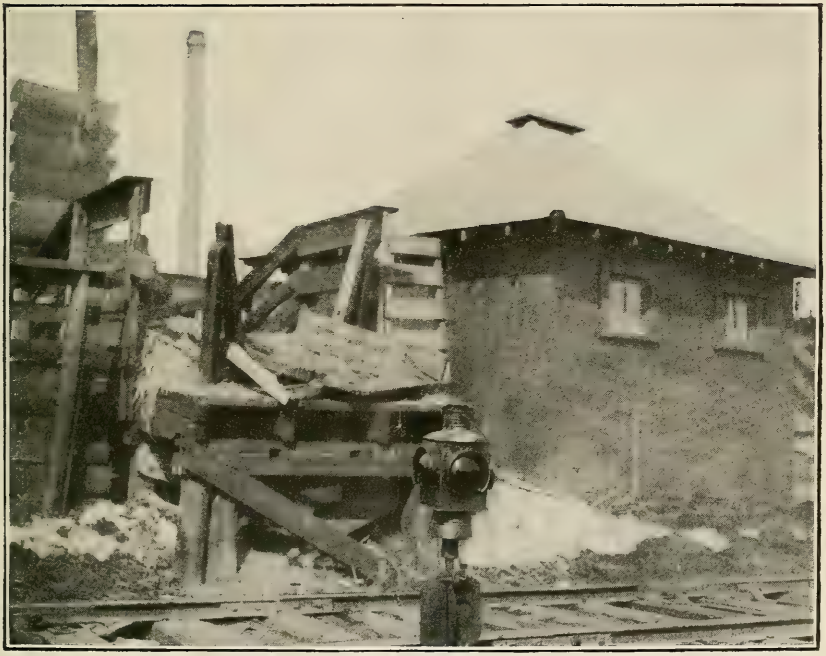


FIG. 2.—A DILAPIDATED LOADING AND UNLOADING CHUTE.

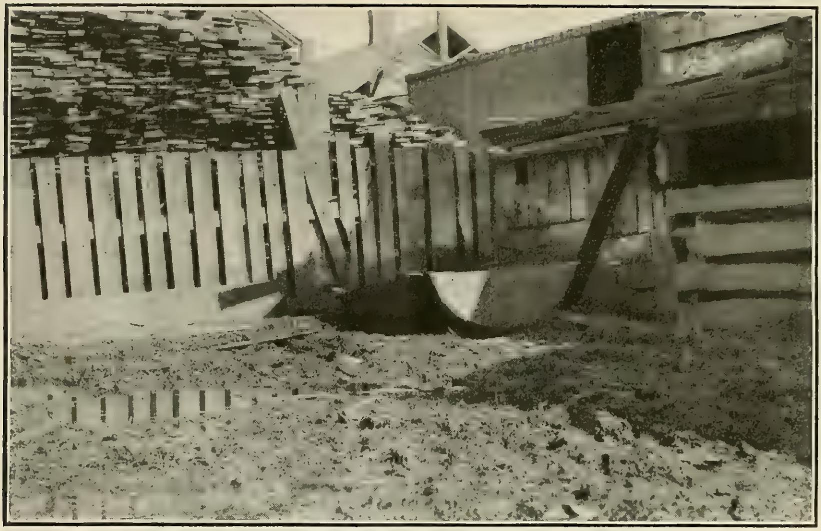


FIG. 1.—YARD SHOWING MUDDY SURFACE AND POOR EQUIPMENT.

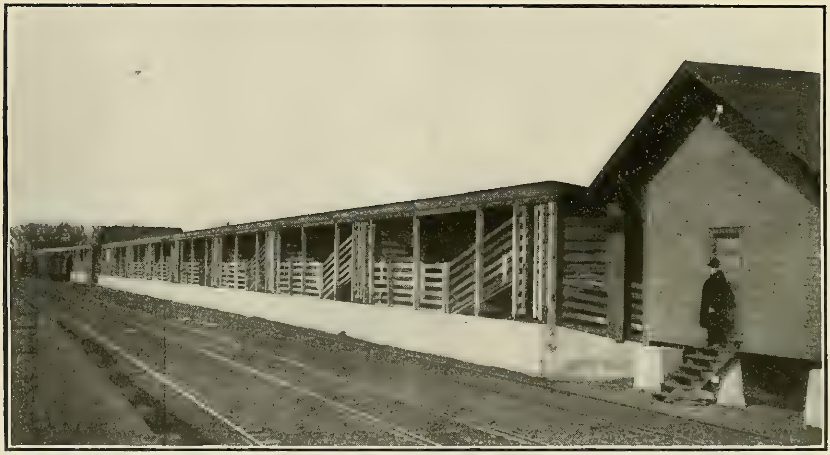


FIG. 2.—SAME YARD AS ABOVE AFTER RECONSTRUCTION.

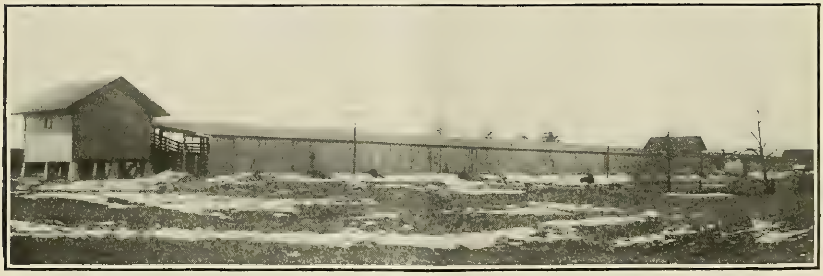
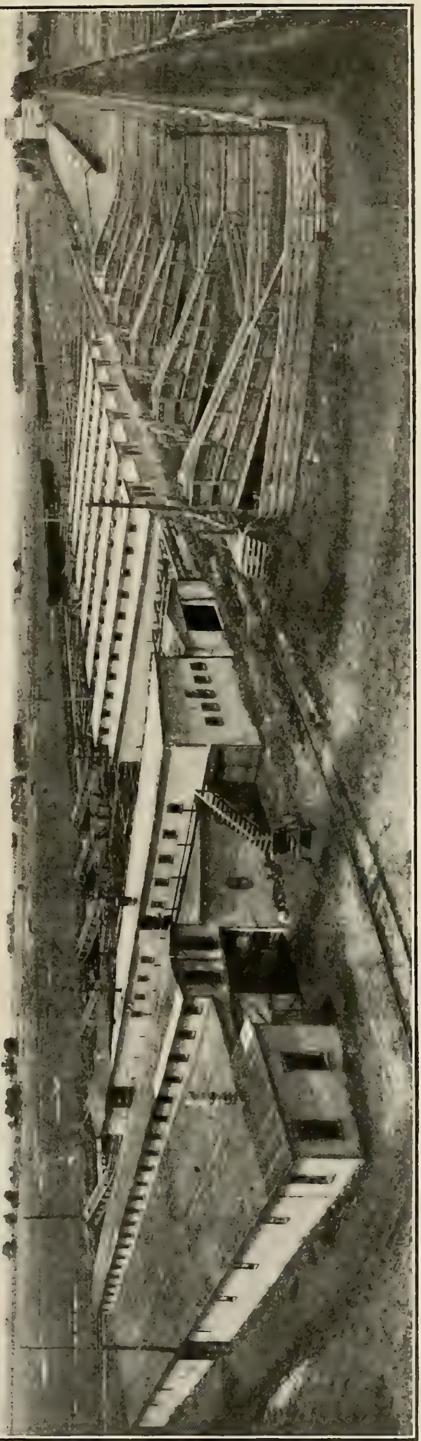


FIG. 3.—BACK OF YARD SHOWN IN FIG. 2, SHOWING PROPER HOUSING FOR PROTECTION OF STOCK IN BAD WEATHER.



GOOD STOCKYARDS BUILT TO REPLACE UNSATISFACTORY YARDS.

### REMOVAL OF INCOMPETENT EMPLOYEES.

In the administration of the law it has been found in some instances that violations have been caused by incompetent employees who have, for one reason or another, disobeyed the official instructions of the roads. There have also been cases where those employed to feed and water the animals had entered into agreements with other employees of the roads to furnish less feed than required by the schedules and divide the amount paid by the shippers for proper service. When these conditions have been made known to the higher officials by the department, it has resulted in many instances in the dismissal of those responsible for such irregularities. The operating officials of a number of roads have adopted systems whereby each shipment of live stock which arrives at the market center is checked, and if any have been confined beyond the statutory period immediate action is taken to locate the person at fault and to discipline, oftentimes by dismissal, the employees responsible for the violations.

### IMPROVED TRAIN SCHEDULES.

Some of the railroads have revised their train schedules to provide for the transportation of live stock to market with greater dispatch so that in some cases it will not be necessary to unload them at all and in others not as often as formerly. Other roads have placed special stock trains in operation, running on certain days each week and maintaining an advertised schedule from the stock shipping centers to the larger markets. These trains make connection with pick-up or local trains of their own and connecting roads, and in this manner have done away with the necessity for unloading in transit many shipments which formerly were stopped at least once for feed, water, and rest.

### VIOLATIONS AND PENALTIES.

Since the enactment of the present law in 1906 there have been reported for prosecution up to and including June 30, 1917, 8,948 violations of the statute, and a total of $426,818.08 has been collected in penalties in the 11 years covered by this period. The administrative officials, however, are more desirous of securing compliance with the provisions of the law than the imposing of penalties.

### FURTHER IMPROVEMENT DESIRABLE.

While much has been accomplished up to the present time, some room for improvement in the handling of live stock still remains. It is believed that if the carriers will cooperate more with the Government better results will be obtained and fewer prosecutions will be required. The department always is glad to furnish the carriers and others with suggestions and all the information it has as to the best methods of handling live stock so as to comply with the terms of the law. Some of the larger roads already have sought such advice and have sent their traffic and operating officials, as well as expert engineers, to points where live stock are handled with the object of improving their methods and facilities. As a result they now give better treatment to the animals and violations of the law are reduced to the minimum. The department on a number of occasions has sent an inspector to feeding points in company with the railroad officials and given suggestions as to the construction of yards and their equipment.

## TEXT OF PRESENT LAW.

AN ACT To prevent cruelty to animals while in transit by railroad or other means of transportation from one State or Territory or the District of Columbia into or through another State or Territory or the District of Columbia, and repealing sections forty-three hundred and eighty-six, forty-three hundred and eighty-seven, forty-three hundred and eighty-eight, forty-three hundred and eighty-nine, and forty-three hundred and ninety of the United States Revised Statutes.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That no railroad, express company, car company, common carrier other than by water, or the receiver, trustee, or lessee of any of them, whose road forms any part of a line of road over which cattle, sheep, swine, or other animals shall be conveyed from one State or Territory or the District of Columbia into or through another State or Territory or the District of Columbia, or the owners or masters of steam, sailing, or other vessels carrying or transporting cattle, sheep, swine, or other animals from one State or Territory or the District of Columbia into or through another State or Territory or the District of Columbia, shall confine the same in cars, boats, or vessels of any description for a period longer than twenty-eight consecutive hours without unloading the same in a humane manner, into properly equipped pens for rest, water, and feeding, for a period of at least five consecutive hours, unless prevented by storm or by other accidental or unavoidable causes which can not be anticipated or avoided by the exercise of due diligence and foresight: *Provided,* That upon the written request of the owner or person in custody of that particular shipment, which written request shall be separate and apart from any printed bill of lading, or other railroad form, the time of confinement may be extended to thirty-six hours. In estimating such confinement the time consumed in loading and unloading shall not be considered, but the time during which the animals have been confined without such rest or food or water on connecting roads shall be included, it being the intent of this act to prohibit their continuous confinement beyond the period of twenty-eight hours, except upon the contingencies hereinbefore stated: *Provided,* That it shall not be required that sheep be unloaded in the nighttime, but where the time expires in the nighttime in case of sheep the same may continue in transit to a suitable place for unloading, subject to the aforesaid limitation of thirty-six hours.

SEC. 2. That animals so unloaded shall be properly fed and watered during such rest either by the owner or person having the custody thereof, or in case of his default in so doing then by the railroad, express company, car company, common carrier other than by water, or the receiver, trustee, or lessee of any of them, or by the owners or masters of boats or vessels transporting the same, at the reasonable expense of the owner or person in custody thereof, and such railroad, express company, car company, common carrier other than by water, receiver, trustee, or lessee of any of them, owners or masters, shall in such case have a lien upon such animals for food, care, and custody furnished, collectible at their destination in the same manner as the transportation charges are collected, and shall not be liable for any detention of such animals, when such detention is of reasonable duration, to enable compliance with section one of this act; but nothing in this section shall be construed to prevent the owner or shipper of animals from furnishing food therefor it he so desires.

Sec. 3. That any railroad, express company, car company, common carrier other than by water, or the receiver, trustee, or lessee of any of them, or the master or owner of any steam, sailing, or other vessel who knowingly and willfully fails to comply with the provisions of the two preceding sections shall for every such failure be liable for and forfeit and pay a penalty of not less than one hundred nor more than five hundred dollars: *Provided,* That when animals are carried in cars, boats, or other vessels in which they can and do have proper food, water, space, and opportunity to rest the provisions in regard to their being unloaded shall not apply.

Sec. 4. That the penalty created by the preceding section shall be recovered by civil action in the name of the United States in the circuit or district court holden within the district where the violation may have been committed or the person or corporation resides or carries on business; and it shall be the duty of United States attorneys to prosecute all violations of this act reported by the Secretary of Agriculture, or which come to their notice or knowledge by other means.

Sec. 5. That sections forty-three hundred and eighty-six, forty-three hundred and eighty-seven, forty-three hundred and eighty-eight, forty-three hundred and eighty-nine, and forty-three hundred and ninety of the Revised Statutes of the United States be, and the same are hereby, repealed.

Approved, June 29, 1906.

## PUBLICATIONS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO THE SHIPMENT OF LIVE STOCK.

### AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Cooperative Live Stock Shipping Association. (Farmers' Bulletin No. 718.)

Marketing Live Stock in the South. (Farmers' Bulletin No. 809.)

How Live Stock is Handled in the Bluegrass Region of Kentucky. (Farmers' Bulletin No. 812.)

A System of Accounts for Live-Stock Shipping Associations. (Department Bulletin No. 403.)

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Contribution from the Bureau of Markets,
CHARLES J. BRAND, Chief.

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# A SYSTEM OF ACCOUNTING FOR FRUIT SHIPPING ORGANIZATIONS.

By G. A. NAHSTOLL and JOHN R. HUMPHREY, *Investigators in Market Business Practice.*[1]

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## INTRODUCTION.

A study of the accounting systems in use in fruit shipping organizations in the West and Pacific Northwest has disclosed a wide variation in methods and forms, for the detail of the accounting procedure has been allowed to be affected greatly by the varying plans of organization, kind of products handled, and local conditions generally.

In standardizing accounting forms and procedure, it was deemed advisable to confine all efforts to devising a system for use in local or assembling associations which market their output through a selling agent and which may or may not operate community packing-houses. Minor modifications of the system and the introduction of other forms may be found advisable in adapting the system to the requirements of associations acting in the dual capacity of assembling and selling organizations, in which case it may be found necessary to provide a record for the segregation of the sale of the fruit by districts. Since there is a wide variation among organizations in this particular, and since local conditions govern the matter, no attempt has been made to cover this point.

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NOTE.—This bulletin should be of interest to all fruit shipping organizations and particularly to those operating under the procedure which now exists in the Pacific Northwest.

[1] J. H. Conn, assistant in Market Business Practice, was actively associated in the devising of the forms and the experimental operation of the system.

After a first-hand study of the conditions prevailing in fruit shipping organizations had been made, the system was devised and installed in eight representative concerns, where its operation was closely supervised. In the final draft of the forms, frequent reference was made to the forms of other systems, as well as to the general procedure now in use in some of the organizations.

The system outlined in this bulletin is intended to cover all operations incident to the handling of growers' supplies and of the growers' fruit, from the time it is received at the packing-house until final returns have been made for it. The aim has been to avoid duplication and to reduce clerical work; care has been used to provide a method applicable to the working conditions of the local offices, which are not always favorable, and to allow for a proper division of labor.

The benefits to be derived from the adoption of a uniform system of accounting are obvious, particularly the possibilities of the interchange of information between organizations, which is now of little or no value on account of the different treatment accorded the accounts in the various organizations. This is true especially in respect to general costs of operation and packing-house costs, and it is hoped that the information contained in this bulletin will aid the organizations in a standardization of these costs.

## BOOKKEEPING.

The bookkeeping for fruit shipping organizations, particularly if they are farmers' organizations, involves several features not found in other lines of business. Numerous important details are to be looked after, some of which, occurring during the height of the shipping season, may seem unimportant and be allowed to pass unrecorded. When, however, their true significance and their relation to the balance of the record is realized, all operations will be suspended until the unfinished work has been brought up to date.

The tendency in some offices to allow a portion of the work to go unrecorded, awaiting the close of the season before entering it, is open to severe criticism. By that time the data may be so widely scattered that it is a difficult matter to accumulate the desired facts. A fixed daily office routine should be adopted, and the accounting work kept up to date. It is incumbent upon the manager to follow the operations of all departments of the business closely, and he should require from the bookkeeper, promptly at the close of the month's business, (1) a trial balance of the general ledger; (2) trial balances of the mercantile and fruit ledgers, the totals of which must agree with the balances appearing on their respective controlling accounts; and (3) a reconciliation of the balance of cash in the bank, appearing on the cash journal, with the balance as shown on the bank pass book or statement.

## OFFICE EQUIPMENT.

The business of shipping fruit is seasonal, and intense work and long hours are the lot of the bookkeepers for a portion of the year. The location and equipment of the office, therefore, should receive careful attention. Good work can not be accomplished in an ill-lighted, poorly ventilated office, or in one so poorly constructed as to render adequate heating impossible. Proper equipment will facilitate the office procedure and justify the expenditure in its purchase in a relatively short time by the elimination of extra help. The equipment should include a fireproof vault, safe, or steel cabinet of sufficient size to contain the records of the business, a suitable desk for the manager, a flat top desk and a standing desk for the bookkeeper, a typewriter and desk, a table, correspondence and record files, a standard adding and listing machine, a check protector, desk trays and clip boards, all of which are necessary and almost indispensable adjuncts of the modern office. If the size of the organization warrants it, the addition of other articles, such as a recording time clock, a mimeograph, a calculating machine, and an intercommunicating telephone system, may be found advisable.

## DESCRIPTION OF THE BUREAU OF MARKETS SYSTEM OF ACCOUNTING FOR FRUIT SHIPPING ORGANIZATIONS.

The following forms and records, grouped in accordance with their intended uses, comprise the system:

Records covering the sale of supplies:
  Form 1. Charge ticket.
    2. Mercantile ledger.
    3. Requisition.
    4. Empty box memorandum.
    5. Box register.
Records showing the receipt and disposition of the fruit:
  Form 6. Crop estimate.
    7. Estimate and order register.
    8. Truck ticket.
    9. Loose-fruit receipt.
    10. Tally sheet.
    11. Packed-fruit receipt.
    12. Register of receipts.
    13. Reconcilement of receipts.
    14. Loading instructions.
    15. Car checker's record.
    16. Inspection record.
    17. Car record.
    18. Manifest.
    19. Invoice.
    20. Pool sheet.
    21. Uniform account sales.
    22. Fruit ledger.
    23. Inventory.
    24. Order register.
    25. Schedule of advances to growers.

General financial records:
- Form 26. Journal.
- 27. Journal voucher.
- 28. General ledger.
- 29. Bills receivable and bills payable record.
- 30. Check.

Records showing the costs of packing-house operations:
- Form 31. Labor-distribution sheet.
- 32. Pay roll sheet.
  - Statement of packing-house costs (p. 25).
  - Statement of warehouse costs (p. 25).

Statistical records:
- Monthly reports (p. 27).
- Financial statement (p. 29).
- Statement of revenue and expenditures (p. 30).

### THE CHARGE TICKET.

The charge tickets (Form 1) on which the sales of supplies to growers are recorded are made in duplicate; the original copies are sent to the office and the duplicates given to the growers for their records. The signature of the grower or of the party receiving the goods is attached to each ticket to show that delivery was effected.

### THE MERCANTILE LEDGER.

The mercantile ledger (Form 2) is made up in the form of a duplicating ledger statement or "bill and charge" ledger. All entries are made in pencil, preferably indelible, over a sheet of carbon paper, the original sheets serving as statements for the growers and the duplicates as the ledger sheets in the office. The sheets have been made wide enough to allow for a full itemization of all transactions. While this is apparently a duplication of work, inasmuch as the growers have copies of the sales tickets in their possession, the relatively small number of the sales and the satisfaction of the growers in receiving statements of charges fully itemized make the practice desirable.

The mercantile ledger contains all growers' accounts, as well as all accounts receivable involving the sale of supplies to other than growers.

### THE REQUISITION.

In many localities the fruit-shipping organizations do not carry a supply of boxes on hand, but deliveries are made to the growers by the mills or box companies as the boxes are needed. Requisitions (Form 3) for the number of boxes desired by the growers are issued on the box companies, and charge tickets are made to cover the sales in order to bring the record of the transactions to the growers' accounts in the regular way. At the end of the month the statements of the box companies are checked against the requisitions issued.

This form of requisition can also be used as authority for the purchase of supplies by employees. The management should insist that all supplies for use in the packing house, warehouse, or office be bought only on written authority, in order to guard against indiscriminate buying on the part of employees and to establish a record in the office as to the liability which has been incurred.

### THE BOX MEMORANDUM.

The use of shipping boxes in the orchards for picking purposes in place of picking or "lug" boxes is very general, although some "lug" boxes are used in nearly all of the districts, and the introduction of the community packing scheme has presented another problem, that of giving the growers proper credit for the number of boxes delivered by them which contain loose fruit for packing and of charging them with the number of empty boxes and boxes containing culls returned to them from the packing house.

The initial sales of box shooks or boxes to the growers must be recorded on the charge ticket (Form 1) in order that the transfer of these assets can be recorded properly and the indebtedness of the growers shown on account of these sales. The loose-fruit receipt (Form 9) acts in the dual capacity of a receipt for the fruit and for the boxes as well. Approximately 70 per cent of the boxes are used in packing out the fruit, leaving the balance to be returned to the growers. The box memorandum (Form 4) is used for recording the number of empty boxes and boxes of culls returned to the growers.

### THE BOX REGISTER.

A separate account is opened with each grower in the box register (Form 5) to record the number of boxes containing loose fruit delivered by him to the packing house and the number of empty boxes, or boxes containing culls, withdrawn by him. Columns have been provided for segregating new and old shipping boxes. The form is made in duplicate. The originals are used as statements to be sent to the growers and the duplicates are retained in the files.

### THE CROP ESTIMATE.

An accurate estimate of each grower's tonnage, by varieties, is an invaluable guide to the sales manager in planning a selling campaign and in the booking of orders prior to the harvest season. The value of the figures depends entirely upon the accuracy of the estimates. In districts where the inspection service is so organized that inspectors, trained in the matter of estimating the crop on the trees, can perform this service or verify the growers' individual estimates, the figures will be dependable and of great value as a means of forecasting the season's production. After the first estimate, constant revision of the figures must be made, taking into account the weather and crop conditions. Form 6 is used for returning this information to the office.

### THE ESTIMATE AND ORDER REGISTER.

The estimate and order register (Form 7) is used to very good advantage as a record of the unsold fruit in a district, based upon the estimates of each grower's tonnage.

The left-hand side of the form presents a record of the growers' estimates, and the right-hand side, a list of the orders which have been accepted for future delivery and of "tramp" shipments or "rollers."

### THE TRUCK TICKET.

A number of organizations employ auto trucks for hauling the growers' fruit to the packing houses. The truck tickets (Form 8) are used as memorandum receipts to record the number of boxes of loose fruit intrusted to the truckman for delivery to the organization. They also provide a record of the hauling performed by the truck. They are made in triplicate. The triplicate copies are given to the growers, the onion-skin duplicates remain in the book for the truckman's record, and the originals are turned in at the office.

### THE LOOSE-FRUIT RECEIPT.

The loose-fruit receipts (Form 9) are made in triplicate. The original copies are given to the growers, the duplicates are sent to the office, and the triplicate cardboards follow the loads through the packing house. A small tin holder is affixed to one of the boxes in which the triplicate loose-fruit receipt is inserted. This serves as a means of identification of the particular lot until packed.

### THE TALLY SHEET.

The packed boxes of fruit are tallied before entering the warehouse on the tally sheet (Form 10). The sheet is used both for tallying the boxes of fruit conveyed from the packing house to the warehouse, and for that received packed from the growers. Columns have been provided on the check sheet for an eight-way grouping of the sizes. A summary at the end of the day of the number of boxes of each size group of the three grades serves as a basis for the inventory of the stock on hand, showing the number of boxes which entered the warehouse.

### THE PACKED-FRUIT RECEIPT.

Great care should be exercised in the tallying of the fruit and the writing of the packed-fruit receipts (Form 11), as the receipts are the original entries of the number of boxes to be credited to the growers' accounts, and on these figures all future computations are based. The receipts are made in duplicate. The originals are retained for the office files and the duplicates are given to the growers.

### THE REGISTER OF RECEIPTS.

Accounts are opened in the register of receipts (Form 12) under the names of the growers in alphabetical order to facilitate reference.

The ruling of the sheets provides for six varieties, although many of the growers will require additional space. Posting is made from the fruit receipts to the register providing a full account of the deliveries made by each grower.

### THE RECONCILEMENT OF FRUIT DELIVERIES.

Reconcilements of fruit deliveries (Form 13) are used very sucessfully as statements or recapitulations of the number of boxes appearing on growers' accounts, classified as to varieties, grades, and size groups. The forms are made in duplicate and copies mailed to the growers with the request that a comparison be made of the number of boxes appearing on the receipts held by them with the total number of boxes of each variety, grade, and size group credited to their accounts on the books of the organization, as evidenced by the totals appearing on the reconcilement forms.

If any discrepancies are found, proper adjustment can be made before the totals are passed for entry into the pool records. This serves principally to rectify any errors made at the receiving door, because of carelessness of drivers in designating the party to whom credit for the load belongs. A thorough recheck of the entries on the register of receipts with the packed fruit receipts should obviate any errors in posting the receipts to the growers' accounts. As soon as the reconcilements have been received from the growers, the totals for each variety are posted to the uniform account sales.

### LOADING INSTRUCTIONS.

Instructions as to loading and specifications of the contents of each load are given on Form 14. Upon the completion of the loading, the shipping clerk returns the "Instructions" with the car tally and a comparison is made in the office to see that the instructions have been executed properly.

### THE CAR CHECKER'S RECORD.

A tally of the load is made by tiers on the car checker's record (Form 15), one side of the page being used for each of the car ends, which are usually distinguished by the terms, "brake end" and "rear end."

For the purpose of substantiating railroad claims, the record of the tally of each car should be complete, including the names of loaders and checkers.

### THE INSPECTION REPORT.

The inspection report (Form 16) serves as the report of the condition of the fruit as made by the inspector before the car is ready to go forward.

### THE CAR REPORT.

The car report (Form 17) serves as a record of the order, spotting, condition, icing, billing, and bracing of the car, for the information of the sales manager.

### THE MANIFEST.

The manifest (Form 18) of the shipment is made on forms provided or recommended by the sales agency. This information is a recapitulation of the car checker's record and shows the contents of the car by varieties, grades, and sizes.

### THE INVOICE.

Organizations disposing of a considerable number of shipments of fruit through other channels than their regularly appointed sales agency will find need for a form of invoice (Form 19) to be used in connection with the sale of the fruit.

### THE POOL SHEET.

The distribution of the amounts received from the sale of the shipments of fruit to the variety pools is made on the pool sheets (Form 20). A separate sheet is used for each variety, and as the net proceeds are received the amounts are credited opposite the number of boxes comprising the particular shipment. Any deductions covering undercharges in freight or claims for allowances which are received by the local oganization after the returns have been made to it by the selling agent are placed in the space provided for deductions and are subtracted from the total of the pool before closing.

This form of pool sheet contemplates the use of an arbitrary differential for grades and size groups to be furnished the local organization by the selling agent and which is based on the economic value of the grades and size groups for the season rather than upon the actual net returns. By means of this differential the net amount of the pool is distributed over the grades and size groups and the average prices obtained are used in calculating the extensions on the uniform account sales. (Form 21).

### SECOND FORM OF POOL SHEET.

A second form of pool sheet is shown under Form 20–A, to be used in organizations which have adopted the method of pooling returns on the basis of actual receipts for each grade. An arbitrary differential is then made for the size groups under each grade, based upon the market experience for the season.

### THE UNIFORM ACCOUNT SALES.

The uniform account sales (Form 21) is so drawn as to exhibit the following essential elements:

Gross value realized f. o. b.
Selling and handling charges.
Proceeds for distribution among the growers.
Average price per box (after all selling and handling charges have been deducted).
Net returns for the variety of fruit.

In order to demonstrate on the account sales the net average price obtained for each grade and size group, all selling and handling charges are deducted before the averages are obtained. Charges for packing, hauling the fruit to the warehouse, sinking fund deductions for investment purposes, or deductions made as partial payments on membership fees, do not affect the net amount obtained for the fruit and are therefore charged direct to the growers' ledger accounts.

### THE FRUIT LEDGER.

The fruit ledger (Form 22), like the mercantile ledger, is made up in the form of a duplicating ledger statement or "bill and charge ledger." It contains the record of the growers' accounts during the fruit season. The sheet is devised especially for entry of credits arising from the sale of the fruit as shown on the account sales. The original sheets are used as statements to the growers and are mailed at the end of the month or as much oftener as it is deemed advisable.

### THE INVENTORY SHEET.

For the purpose of conducting a perpetual inventory of the stock of fruit on hand in the warehouse, the necessary information can be made available daily by adding the total number of boxes received into the warehouse to the balance on hand and deducting the total of the number of boxes shipped out. The inventory sheet (Form 23) is devised for that purpose.

### THE ORDER REGISTER.

All orders on account which have been accepted by the organization to be filed against the accounts of growers should be recorded on Form 24. The register should be held for ready reference when advance payments are made to growers and as a check on the work of the bookkeeper when returns are being mailed out.

### THE SCHEDULE OF ADVANCES TO GROWERS.

The net proceeds of the sales of apples and pears are usually pooled for the entire season. Owing to the delay in closing the pools by reason of export shipments or unavoidable delays in disposing of the fruit, advance payments are made as the receipts from the sales justify. As a rule, shipping organizations also make advances to their members at harvest time at a flat rate per box on the basis of the growers' estimates or on the deliveries to the warehouses. These credits are not written into the accounts, but a schedule is made up showing the debit balances owing on the growers accounts and the amount of credit on which the advances are to be based.

The schedule of advances to growers (Form 25) is ruled to take care of both equalizing and variety advances.

### THE CASH JOURNAL.

The cash journal (Form 26) is a combination of the cash book and the journal. The incorporation of these two books into one form and the columnar development of the form tend to facilitate the classification of entries and to minimize the posting to the ledger. No special forms are provided in the system for the recording of purchases and sales, but the cash journal is used for the journalizing of these items as well.

Effort has been made to reduce the size of this form by limiting the number of special columns to those having sufficient items each month to warrant economy in their use. A book of moderate proportions will be found much more convenient to handle and to operate than one containing a large number of columns, if the needs of the business are not such as to necessitate the additional columns.

The captions of the columns of the cash journal are as follows:

Debit side: Date; cash; bank deposits; folio; general ledger; mercantile ledger; fruit ledger; fruit returns; merchandise; blank.

Credit side: Cash; journal voucher number; check number; bank withdrawals; general ledger; folio; mercantile ledger; fruit ledger; boxes; paper; nails; spray; fruit sales; merchandise; blank.

### THE JOURNAL VOUCHER.

A form of journal voucher (Form 27) is used for recording a full explanation of each transaction in detail which may be written on a typewriter instead of writing the explanation of the entry in the journal proper. The journal voucher also serves as a permanent record of the detail of budget entries, such as charges to growers' accounts, arising from sales as recorded on the charge tickets. The journal entry, if made in budget form, records the total amount chargeable to the growers' accounts in the mercantile ledger and the totals of the offsetting credits to the proper supply accounts. Posting to the growers' accounts is then made in detail directly from the charge tickets to the mercantile ledger. All other budget entries, such as the payroll, advances to growers, and the credits arising from the uniform account sales, should be handled in a like manner. All supporting papers, including invoices for purchases, may be attached to the journal vouchers, and each voucher should bear the signature of the person authorizing the entry. A form of receipt has been appended for use in case of disbursements of petty cash when the payee is unable to furnish a receipted bill.

### THE GENERAL LEDGER.

No special form of general ledger leaf need be made up, but the usual stock form will meet every requirement. Many bookkeepers prefer the two-column ledger leaf, but the center column balance ledger leaf appears to be gaining favor rapidly.

### THE BILLS RECEIVABLE AND BILLS PAYABLE RECORD.

The bills receivable and bills payable record is used as a subsidiary record showing the date, name of drawer, name of drawee, due date, rate of interest, amount and remarks. The bills receivable and bills payable accounts in the general ledger are the controlling accounts and the total of the items appearing in the note record, as owed or owing, must agree with the balance appearing on the above corresponding accounts. A number of standard forms of note records are now on the market which can be adapted to the requirements of shipping organizations.

### THE CHECK.

The usual form of commercial checks are used, and these should be numbered and bound in pads. Entry should be made in the journal direct before the check is written. Many bookkeepers have acquired the habit of registering the checks drawn on check stubs or small check registers, allowing the entry in the journal to await their convenience. This is merely a duplication of work and moreover means additional labor in accounting for the payment, when the details of the transactions have been forgotten.

### THE LABOR DISTRIBUTION SHEET.

In order to arrive at an accurate segregation of labor costs in both the packing house and the warehouse, it is advisable to place in the hands of the foreman a daily record upon which this segregation is to be made. The labor distribution sheet (Form 28) serves as a time book and as a means of segregating the labor costs.

### THE PAY ROLL.

The pay roll (Form 29), both from the standpoint of a voucher for the distribution of cash, and as a record of the segregation of labor costs, is a sheet of considerable importance. This sheet is written up from the labor distribution sheets, after they have been approved by the foreman of the packing house and of the warehouse. It is advisable to secure the signatures of the payees on the pay roll as an acknowledgment of the receipt of the checks. If it is desired, the cover of the binder can be bound so as to fold back, exposing to view the pay roll number, check number, and the column for signature of the employees.

## METHOD OF OPERATING THE SYSTEM.

### THE RECORDING OF THE PURCHASES AND SALES OF SUPPLIES.

The purchases of supplies are recorded on the journal vouchers, to which are attached the invoices as evidence for incurring the liability. Owing to the limited number of accounts payable necessary, a separate account is opened with each creditor. Small monthly accounts, covering expenses, such as telephone, telegraph, electric light and power bills, need not be recorded as accounts payable, but can be treated as cash items.

Entry is made from the journal vouchers to the cash journal and the items are extended in the proper columns. A special column has been provided for merchandise, as the commodities grouped under this caption will be bought at frequent intervals.

The sales of supplies to growers are recorded on the charge tickets (Form 1). After the numbers of the tickets are checked to ascertain that all are accounted for, the prices, extensions, and footings are audited and the tickets are placed in alphabetical order and renumbered. A listing is then made of the new numbers of the tickets and the segregation of the items on a journal voucher, which becomes the basis for a journal entry, debiting sundry growers' accounts and crediting boxes, spray, or whatever sales accounts are affected in totals. Posting is made direct from the charge tickets to the accounts in the mercantile ledger, the ticket numbers being used as reference to the files. At the close of the month the balances appearing on the accounts are forwarded to new sheets for the succeeding month and the statements are sent to the growers. In this way the members can be provided with monthly detailed statements of their accounts with the organization.

When boxes, paper, and nails are transferred from stock to the packing house to be used there in packing the fruit, a memorandum of the transfer should be made by the warehouseman to serve as a basis for a journal entry, charging the packing-house account and crediting the proper supply accounts. The price set upon such transfers should be cost plus a reasonable charge for handling.

### RECORDING OF CROP ESTIMATES.

Posting is made from the crop estimates (Form 6) to the left-hand page of the register (Form 7), under the caption "Estimates," showing the number of boxes of a given variety of fruit which it is estimated will be produced by the members during the season. The footing of the estimate column, less a reasonable allowance to safeguard against overselling, gives the approximate total of the number of boxes of a particular variety to be marketed. A percentage key of grades and sizes, based upon the experience of previous years and the condition of the current year, is applied to the total number of boxes estimated, segregating each variety into grades and size groups. The results are extended in the "unsold balances" columns.

The right-hand side of the book comprises a listing of the orders accepted and of the shipments tramped. The excess of the tonnage estimated over that already disposed of represents the approximate remainder still on hand and unsold.

### RECEIVING THE FRUIT.

Upon delivery of the loose fruit to the packing house, a loose-fruit receipt (Form 9) is made in triplicate, the triplicate cardboard copy remaining with the lot until it is packed out. If the hauling is done by a community truck, a comparison of the truck tickets with the loose-fruit receipts is made as to the number of boxes and varieties. The duplicate loose-fruit receipts merely serve as a record to be retained in the office, while the triplicate receipts are held in the packing house. As the triplicates do not reach the office in consecutive order, their numbers must be checked carefully to see that none are missing. A comparison should be made with the packed-fruit receipts as to the number of boxes and the varieties packed out, the rule being that the number of packed boxes should approximate 65 per cent to 70 per cent of the number of boxes of loose fruit. A cross index between the packed fruit and the loose-fruit receipts is established by placing the number of one on the other.

The packed boxes are tallied on the tally sheet (Form 10) either after they have been sent back from the nail press or, if a conveyor system is used, as the fruit passes a given point on the way to the warehouse. The packed-fruit receipts (Form 11) are written up from the tally sheet in the office at the end of the day, and the number of the receipt is placed in the space provided for that purpose on the tally sheet. If any of the lots of fruit are only partially packed out, this fact is indicated on the tally sheet and the receipt for packed fruit is not written until the final figures are available.

The method of tallying fruit on the tally sheets and recording it on the packed-fruit receipts as outlined applies to the boxes packed in the community packing houses. The same forms can be used for recording the receipt of fruit packed by the growers. The tally sheets then serve as a tally of the fruit received at the door of the warehouse, and the fruit receipts are written by the receiving clerk. All receipts for fruit packed by the growers should be marked "Growers' pack" with a rubber stamp, so that proper notation to that effect will be made on the register of receipts.

### REGISTERING THE RECEIPTS.

The packed-fruit receipts are placed in alphabetical order to facilitate entry to the credit of the respective growers' accounts in the register of receipts. The entries should be checked back daily, so that any errors in posting can be located immediately. At the end of the delivery season the boxes appearing on the growers' accounts are totaled and the footings are transferred to the reconcilements of fruit deliveries (Form 13), which serve as statements to be sent to the growers for comparison with their records. If the latter form is not used, the transfer of the totals of the various varieties is made direct to the account sales (Form 21).

### THE RECORD OF GROWERS' BOXES.

The record of the sales of boxes or box shooks to the growers is made on the charge tickets (Form 1). The loose-fruit receipt (Form 9) demonstrates the number of boxes containing loose fruit delivered to the packing house, and postings of these items are made to the box register (Form 5). The regular shipping boxes are used in most districts for picking boxes, and the growers are therefore entitled to withdraw from the packing house approximately 30 per cent of the total number of boxes delivered. The record of the withdrawals is made on the box memorandum (Form 4), and these are posted to the box register under the heading "Withdrawals." At the end of the delivery season the overage or shortage on each grower's box account is ascertained and the respective ledger accounts are then charged or credited with the difference. The following journal entry is made to carry these items into the financial records: Debit, growers' accounts for overages; credit, growers' accounts for underages. Debit or credit, box account for the net amount of withdrawals.

### RECORD OF THE SHIPMENTS.

Upon completion of the loading of a car the loading instructions (Form 14), car checker's report (Form 15), inspection report (Form 16), and car report (Form 17), are sent to the office, and the manifest (Form 18), invoice (Form 19), and bill of lading are prepared by the billing clerk. Whether the shipment is sold outright, tramped, or consigned, the record is held in memorandum form until the net proceeds of the sale are received.

### THE POOLING RECORDS.

On the day following the loading of the cars posting is made of the totals of the number of boxes of each variety contained in the various shipments from the manifest to the respective pool sheets. As the remittances for the shipments are received, entries are made in the cash journal, debiting cash and crediting fruit sales for the amounts. A segregation of the proceeds is then made on the pool sheets to the respective pools, opposite the number of boxes shipped. When all the shipments of a given pool have been paid for, the average price per box in each grade and size group is ascertained on the basis of a differential reflecting the selling experience for the season. The average prices thus obtained, less the handling and other charges, are used in making the extensions on the account sales.

To facilitate the work at the time of closing the pools and as soon as the reconcilements of fruit deliveries have been returned by the growers, the uniform-account sales (Form 21) are written up, as to the names of the growers, addresses, and the number of boxes of each grade and size group. The total number of boxes of each grade shipped out, as shown on the pool sheet, should be compared with the total number of boxes received as recorded on the uniform-account sales. If the reconcilement forms are not used, the uniform account sales can be written up directly from the register of receipts.

In order to preserve a record of the totals of the number of boxes in each grade and size grouping, and later of the totals of the extensions made on the account sales, a statement of these totals is made on a special sheet. A copy of this sheet should precede the account sales written up for each variety, and it is well to attach to it the adding-machine listings showing the detail of the above amounts. Inasmuch as but few of these sheets will be necessary, no special form has been devised, but a copy of the account sales form can be used for this purpose.

After the average prices have been obtained from the pools they are placed opposite the respective numbers of boxes on the account and the extensions are made and totaled. Proof of the accuracy of the work should be established by comparing the grand total of the extensions made on the account sales with the extensions of the total number of boxes in each grade and size group at the average prices as shown on the recapitulation sheet.

When the account sales have been completed, a listing of their numbers and the amounts to be credited to the growers' accounts is made on a journal voucher and an entry is passed as follows: Debit—fruit returns; credit—warehouse revenue, labeling revenue, inspection revenue, sundry growers' accounts; debit or credit overage and underage account with the overage or underage in the above calculations.

Space has been provided on the pool sheet for recording the above journal entry in order that the distribution of the pool may be shown in complete form.

At the end of the season for selling supplies all debit balances appearing in the mercantile ledger are transferred to the respective accounts in the fruit ledger. Even prior to the closing out of the mercantile ledger balances into the fruit ledger, all charges, other than for supplies, and which are directly deductible from the returns of the fruit, are posted to the fruit ledger. Among such items are included charges for packing and hauling, for advances, and for investment purposes, as payments on membership fees or subscriptions to capital stock.

The net amounts shown on the account sales are credited to the respective growers' accounts in the fruit ledger, and checks are sent to the growers to cover the credit balances.

### PREPARATION OF SCHEDULE OF ADVANCES TO GROWERS.

The schedule of advances on fruit to growers (Form 25) is designed for both equalizing and variety advances. In the preparation of the schedule, a listing is made of the names of the growers and the debit balances owing by them. For the "equalizing" advance, the number of boxes on which the advance is to be computed is shown in the column under that heading, and extensions are made in the adjoining column on the basis of the average rate per box. The amount of the advance over the debit balance is then ascertained and listed. If an overdraft exists, the fact is noted in the column provided for that purpose.

The ruling for the variety advances segregates the extra-fancy and fancy grades and provision has been made for two groups of varieties taking different rates of advances. Columns have been provided for displaying the amounts applied on notes due the organization by the growers and for the checks issued in partial or full payment of crop orders and mortgages. The amounts for which the checks are issued to the growers are shown in the "Amount of check" column and the check numbers are placed in the adjoining column. As soon as the work is completed a journal entry is made as follows: Debit—sundry growers' accounts; credit—bank withdrawals for the amount of the checks issued to growers and applied on crop orders and mortgages, bills receivable for the amounts applied on the growers' notes.

Posting is made from the schedule to the growers' accounts in the fruit ledger and to the credit of the bills receivable account in the general ledger. Great care should be exercised that indorsement of the amounts applied on the notes is made on the backs of those documents and in the bills receivable record, and that proper notation of the amounts paid on crop orders and mortgages is made in the record of orders on account (Form 24).

### LABOR RECORDS.

The labor distribution sheets are arranged to accommodate the payment of the pay roll at semimonthly intervals. The foremen of the packing house and the warehouse fill out the labor distribution sheets (Form 28) and the totals as shown thereon are transferred to the pay roll (Form 29).

On the reverse side of the sheet the segregation of the labor costs is made, which is used as the basis for the entry in the cash journal as follows: Debit, various packing-house and warehouse expense accounts affected. Credit, bank withdrawals.

It is not necessary to transcribe the checks into the cash journal in detail, but the entry is made in that book in total. The canceled checks are checked off on the pay roll.

A segregation of the packing-house and warehouse costs as outlined will be found of great value to the management in the conduct of the business and for comparative purposes.

### THE CASH JOURNAL.

The cash journal (Form 26) provides a chronological record of the financial transactions of the business and combines the features of the cash book, journal, sales book, and purchase book. All transactions must be journalized in detail or in budget in the cash journal; consequently no items can be posted to the ledgers except those appearing in this book.

#### DEBIT COLUMNS.

*Cash.*—All receipts of cash of whatever nature are entered in the cash column, the corresponding credits being made to the proper accounts affected.

*Bank deposits.*—The amounts of the deposits made in the bank are entered in the bank-deposit column. The bank balance, as shown by the cash journal at the end of the previous month, is carried forward to the head of the bank-deposits column for the current month, making it possible to ascertain at all times the available amount of money in the bank by deducting the footing of the withdrawals column from the footing of the bank-deposits column.

*General ledger.*—This column may be used for all items to be posted to the debit of the accounts in the general ledger, and for which no special columns have been provided. Posting should be made in detail from this column to accounts in the general ledger.

*Mercantile ledger.*—All items to be posted to the debit of growers' supply and mercantile accounts should be entered in the mercantile-ledger column, and posted in detail to the mercantile ledger. At the end of the month the column total is posted to the debit side of the mercantile-ledger controlling account in the general ledger.

*Fruit ledger.*—In the fruit-ledger column are entered all charges which are deductible from the net returns from the growers' fruit. Postings are made in detail from this column to the accounts in the fruit ledger. At the end of the month the total of the charges is posted to the debit side of the fruit-ledger controlling account in the general ledger.

*Fruit returns.*—In this column are extended the amounts chargeable to the fruit-returns account, offsetting the credits to growers' accounts arising from the sale of fruit handled for them and the revenue accruing to the organization.

*Merchandise.*—All purchases of merchandise, such as grain, hay, feed, flour, salt, and the freight charges thereon, are extended into this column, and posting of the total of the column is made at the end of the month to the debit of the merchandise account.

### CREDIT COLUMNS.

*Cash.*—The cash column carries all items of cash of whatever nature which are disbursed by the organization either for petty expenditures or to be deposited in the bank. It should be a strict rule that all cash receipts are to be deposited in the bank when it is possible to do so. It is sometimes found inexpedient to adhere strictly to this rule because of infrequent petty expenditures, and for that reason a cash column on the credit side of the journal has been provided. Where a petty cash fund is in use, the credit-cash column need not be used, since deposits may then be indicated by transfer of daily totals of incoming cash from the debit-cash column to the bank-deposits column.[1] A receipt should be taken for every expenditure of cash and all disbursements of $1 and over should be paid by check.

*Bank withdrawals.*—In the bank-withdrawal column are extended the amounts of all checks drawn on the bank.

*General, mercantile, and fruit ledgers.*—These columns serve the same purposes on the credit side as were explained on the debit side, the postings being made to the credit side of the ledger accounts in this instance.

*Boxes, paper, nails, and spray.*—These columns carry all credits arising from the sale of supplies.

*Fruit sales.*—All remittances from the sale of fruit are extended in the fruit-sales column.

*Merchandise.*—In the merchandise column are extended all sales of merchandise, such as hay, grain, feed, and flour.

## THE LEDGER.

The ledger is the book of accounts. After the transactions of the business have been recorded in the cash journal the debit and credit items arising from such transactions are transferred or posted to the proper accounts in the ledger. In this way all of the debits and credits pertaining to a particular person or subject are collected in a ledger account under a proper caption, making it possible to view and consider the account as a whole.

The ledger is divided into three parts and designated as the mercantile ledger, the fruit ledger, and the general ledger. This is done partly to facilitate the handling of the accounts and partly to allow the use of special forms for the mercantile and fruit ledgers which tends to reduce the work materially.

### THE GENERAL LEDGER.

The general ledger contains all of the accounts other than those falling within the scope of the growers' mercantile ledger and the growers' fruit ledger. It includes also the limited number of accounts payable which it will be necessary to open with creditors. In order to make the general ledger complete in itself and to include all the elements necessary to effect a trial balance, controlling accounts for the mercantile and the fruit ledgers are opened in the general ledger. Further explanation of this very important principle in modern accounting is given in the description of the controlling accounts for the mercantile and fruit ledgers.

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[1] Directions for operating petty cash funds are set forth in detail in U. S. Department of Agriculture Bulletin No. 178, "Cooperative Organization Business Methods."

### EXPLANATION OF GENERAL LEDGER ACCOUNTS.

*Capital stock.*—All sales of capital stock are credited to this account and the credit balance measures the amount of capital fully paid up, for which certificates of stock are issued and outstanding.

In cooperative organizations having no capital stock a membership fee is usually required from members for the purpose of providing a working capital. From an accounting standpoint this represents capital invested in the business and its value should be maintained. The treatment of such contributions of capital is practically the same as under the stock plan.

In organizations where a membership fee is paid each year by the members at the time they contract with the organization for the handling of their fruit these fees are looked upon as revenue, and are used to defray operating expenses.

*Land, buildings, and spur track.*—The cost of the land, packing-house, and warehouse should be set up in accounts under those captions.

In many instances it has been found necessary for the shipping organizations to pay for the grading, construction, and the ties for the spur track leading from the main line of the railroad to the warehouse. The cost of these items is charged to spur track account.[1]

*Equipment accounts.*—All items of furniture and equipment used in the office are charged to office equipment account. The cost of the equipment of the packing house is shown in the packing-house equipment account and that of the warehouse in the warehouse equipment account. Repairs and renewals should be charged to expense.

*Cash.*—The excess of the total of the "cash" column on the left-hand side of the cash journal, representing the receipts of cash, over the footing of the "cash" column on the right-hand side of the cash journal, representing the amount deposited in the bank and disbursed as petty cash, demonstrates the amount of cash on hand. In order to avoid the necessity of referring to the cash journal for the amount of cash on hand when taking a trial balance, an account under the caption "cash" is opened in the general ledger and the balance of the cash on hand carried to it at the end of the month.

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[1] Several large shipping organizations have written off the entire investment in spur tracks over a period of three to five years.

*Bank.*—The excess of the total of the bank deposits column in the cash journal, representing the amount of the deposits plus the balance carried forward from the previous month, over the total of the bank withdrawals columns, representing the amounts disbursed, demonstrates the available amount of cash in the bank at the end of the month. This balance is posted to the account under the caption of the name of the bank. If it is desired to have the bank account in the ledger show the amount of receipts and disbursements of cash, the totals of the bank deposits and bank withdrawals can be posted to the account at the end of each month instead of posting the balance.

*Supply accounts.*—It is usually desirable to ascertain the gross profits on the various lines of supplies handled. To open an account with each commodity, however, would result in a great variety of segregation and supplies are therefore grouped, as a rule, and accounts opened under the following captions: Spray; boxes; paper; nails; labels and labeling; miscellaneous.

These accounts are debited with the cost of the commodity and the freight charges. They are credited with the total sales. They are also debited with the amount of goods returned by customers and credited with the cost of goods returned by the organization.

The label account also includes cost of paste and the labor in affixing labels to the boxes. The labels are usually bought and delivered in one lot, making but one charge to the account for that item. Hence it does not appear necessary to open another account for the actual work of labeling.

*Merchandise.*—Besides the orchard supplies, such as boxes, paper, nails, spray materials, ladders, etc., which are handled by practically all fruit-shipping organizations, some also deal in grain, hay, feed, flour, etc. In order to differentiate between the growers' supplies and these commodities, an account under the caption "Merchandise" is opened to record their purchase and sale.

*Bills receivable and bills payable accounts.*—The bills receivable account shows the amount due on signed obligations and includes membership notes and drafts which have been accepted. The bills payable account shows the amount owing by the organization on signed obligations.

*Controlling accounts for the mercantile and fruit ledgers.*—The controlling or summary accounts will disclose in condensed form through posting of monthly totals the transactions that are posted in detail from day to day in either of these ledgers. At the beginning of the season the mercantile ledger controlling account is debited with the total of all the balances appearing on the mercantile ledger, as shown by the trial balance. The account is currently debited with the total of the column headed "Mercantile ledger" on the left-hand side of the cash journal and is credited with the total of the "Mercantile ledger" column on the right-hand side of the cash journal. The resulting balance will be the total of the balances appearing in the mercantile ledger. The fruit-ledger controlling account is operated in like manner.

*Accounts payable.*—The comparatively small number of creditors' accounts warrants the opening of an individual account with each. The credit balance appearing on any one of these accounts measures the amount due that particular creditor.

*Fruit sales.*—Instead of opening one account under the caption "Fruit account," to which are credited the receipts from the sales of fruit and to which are debited the gross returns made to growers, two accounts are opened under the captions "Fruit sales" and "Fruit returns."

The fruit sales account is credited with the amount of the receipts from the sales of fruit and is debited with all allowances made after the payment has been received. The credit balance appearing on this account is the net amount of money received from the sale of fruit. It is practically the controlling account for the distribution to the various pools.

*Fruit returns.*—The fruit-returns account is debited with the gross amount of returns made to the growers. The debit balance appearing on this account represents the total amount paid to growers, and should equal the credit balance appearing on the fruit-sales account.

*Overage and underage account.*—In closing down the pools on fruit, it is usually the case that there remains a small balance which can not be apportioned over the number of boxes at even cents or mills. In order to clear the fruit sales account of these unapportioned balances, they are credited to overage and underage account. Conversely, other pools may lack but the equivalent of a fraction of a cent per box of paying out. The accumulations in this account are then used to supply the deficiency.

*Building fund accumulations.*—The financing of the construction of warehouses and packing houses, the purchase of the land, and the construction of the spur track is usually accomplished by means of a loan. This indebtedness is liquidated over a period of 3 to 5 years by deductions at a given rate of 3 to 6 cents per box on the fruit handled for the growers. The credit balance appearing on this account is the amount of the accumulated deductions. As fast as the building loan is paid off, shares of stock or other evidences of the property interests of growers in the property of the association may be issued.

*Undercharges.*—All items of undercharges in freight, icing, demurrage, diversion, and switching are credited to this account pending their adjustment. When organizations merely pack, warehouse, and load the fruit, but do not sell it, their selling agents usually attend to these matters.

Against shipments originating from outlying points there is sometimes a differential in freight of from 2 to 15 cents per hundred when destined to certain markets. The amount of this freight arbitrary is held in the undercharge account as a protection against possible claims from buyers. After a sufficient lapse of time a portion at least of the sum accumulated can be written back into the respective pools.

*Claims.*—All amounts received in payment of claims against the railroad companies are credited to the "Claims account." If the amount is sufficiently large, a disbursement is made to the growers participating in the pool of the fruit on which the claim originated. Otherwise the balance is transferred to the profit and loss account at the end of the year.

*Revenue accounts.*—An account is opened under the caption "Warehouse revenue" to accumulate the deductions made from the account sales for warehousing the fruit. The packing-house revenue account is credited with the amounts charged to the growers' accounts to cover the cost of packing the fruit.

In organizations where separate charges are made for labeling and inspection, the amounts of these deductions from the account sales are accumulated in the labeling revenue account and inspection revenue account.

If the organization owns and operates a truck or contracts the hauling of the fruit from the orchards to the packing house, the revenue derived from that source is credited to hauling revenue account, as the charges are made against the respective growers' accounts. A separate account is opened with "Truck expense" if the truck is owned by the association, in order to accumulate the costs of operation. If the hauling is done under contract, an account is opened under the name of the contractor for recording the payments made on the contract.

*Interest.*—To the interest account are charged all items of interest on notes payable, including bank discount. The account is credited with all items of interest accruing from notes receivable.

*Box making.*—The cost of making boxes is shown by this account. It will be necessary to open the account only in concerns selling made-up boxes to the growers.

*Expense accounts.*—A segregation of the office expenses and those pertaining to the conduct of the business in general is made by means of accounts under the following captions: Expense, advertising and printing; Auto; Drayage; Insurance and taxes; Labor (not chargeable directly against packing-house or warehouse operations); Legal; Light, heat, and water; Office supplies and stationery; Postage; Salaries; Telephones and telegraph; Traveling; Miscellaneous. The balances appearing on these accounts at the end of the year are closed into the profit and loss account.

*Packing-house expense.*—The segregation of the packing-house pay roll is made under the following items, for which accounts are opened in the ledger: Packing house—salaries of clerks, foreman, etc.; receiving; sorting; floorwork, floormen, and truckers; packing; pressing and stenciling; miscellaneous.

Accounts are also opened under the following captions for segregating the cost of supplies and of expenses, other than labor, pertaining to packing operations: Packing house—boxes; paper; nails; light and power; repairs.

*Warehouse expense accounts.*—The warehouse expenses are segregated under the following accounts: Warehouse—labeling; trucking; loading of cars; salaries of foreman, car checkers, etc.

*Car bracing lumber and paper.*—Under this are included all materials used for bracing cars, such as 2 by 4's, 1 by 6's, and car strips; also paper and straw used for car linings. The account is charged with the various items as they are purchased and at the end of the shipping season is credited with the value of the materials on hand. The balance appearing on the account, representing the cost of the goods used in bracing the cars, is transferred to the warehouse account.

*Reserve for depreciation.*—Owing to the peculiarities of the fruit business, heavy allowances should be made to cover the depreciation on buildings and equipment.

Instead of writing down the value of office equipment, packing-house equipment, and warehouse equipment, to cover the ordinary wear and tear or depreciation on these assets, it is a better plan to set up a reserve for this purpose under the caption "Reserve for depreciation on equipment." This is accomplished by charging "Profit and loss" and crediting "Reserve for depreciation on equipment" account at the close of the year.

As in the case of equipment, the depreciation of buildings is set up in a reserve account under the caption "Reserve for depreciation on buildings." By itemizing the credits on the ledger account the amount set aside for depreciation on the packing house and that set aside to cover the depreciation on the warehouse can be ascertained at any time.[1]

*Reserve for bad debts.*—Uncollected balances on accounts receivable are often carried into the succeeding year's business at full face value and are afterwards found to be uncollectible. To charge these uncollectible items off during the succeeding year would throw the full burden of loss upon the business of a year in which it was not incurred. A better policy is to set aside out of each year's profits a sufficient sum to cover the estimated losses on bad debts. The balances of the accounts found to be uncollectible are then charged to this account. Should any of the past due items thus charged off be collected later, they will then be credited to surplus. By showing the name of all uncollectible balances on this account a very definite record of them is established. The credit balance appearing on this account is the available amount reserved against losses from bad debts. On the balance sheet it should not appear as a liability on the credit side but as a deduction from the total amount due from growers on the asset side.

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[1] For further discussion of the subject "Depreciation" see U. S. Department of Agriculture Bull. No. 178: Cooperative Organization Business Methods. 1915.

*Packing-house closing account.*—This account is raised on the books at the end of the year for the purpose of assembling in one account the expenses and revenue derived from packing-house operations, so that these may be shown in their proper relations. The balance appearing on this account is transferred to the profit-and-loss account at the time of closing the books.

The same procedure is followed for the closing of the warehouse operations into the warehouse closing account.

*Profit and loss.*—The accounts containing profit-and-loss elements are brought together in this account at the end of the year for the purpose of determining the net profit or loss for the year.

*Surplus.*—The credit balance appearing on this account measures the amount of undivided profits remaining in the business. The net profit or loss at the end of the year is transferred from the profit and loss account to the surplus account. The operation of a business at a net loss will result in a debit balance, or deficit, in the surplus account.

## COST STATEMENTS.

A statement of the average costs of packing-house and warehouse operations may be shown by means of the following arrangement:

*Statement of packing-house costs.*

| Number of boxes packed | Amount. | Average per box. |
|---|---|---|
| Salaries of foreman and clerks | | |
| Receiving | | |
| Sorting | | |
| Floor work, floor men, and truckers | | |
| Packing | | |
| Pressing and stenciling, including labor, nails, and stencils | | |
| Miscellaneous | | |
| Boxes | | |
| Paper | | |
| Sundry supplies | | |
| Light and power | | |
| Repairs | | |
| Insurance and taxes | | |
| Depreciation of building and equipment | | |
| Administration and accounting | | |
| Total packing cost ... per cent | | |
| Packing-house revenue, 100 per cent | | |
| Net revenue, difference ... per cent | | |

*Statement of warehouse costs.*

| Number of boxes packed | Amount. | Average per box. |
|---|---|---|
| Salaries of foreman and checkers | | |
| Trucking | | |
| Loading cars | | |
| Car bracing lumber, paper, etc | | |
| Labeling | | |
| Light and power | | |
| Repairs | | |
| Sundry supplies | | |
| Insurance and taxes | | |
| Depreciation of building and machinery | | |
| Administration and accounting | | |
| Total warehousing costs ... per cent | | |
| Warehouse revenue, 100 per cent | | |
| Net revenue, difference ... per cent | | |

### MONTHLY REPORT TO THE BOARD OF DIRECTORS.

In order that the directors may be kept informed fully as to the progress of the business, it is advisable that a monthly report be submitted, including the statements given below. This report must not be considered as a statement of the exact financial condition of the business, as such a statement could be obtained only through an inventory of the supplies on hand, by taking into consideration the revenue accrued on unclosed pools, and by a "closing of the books" in the regular way. A report of this kind would, however, present to the directors many matters in which they are greatly interested.

### TRIAL BALANCE OF THE GENERAL LEDGER.

A copy of the monthly trial balance of the general ledger should be included in the report. While the trial balance constitutes nothing more than a transcript of the balances appearing on the ledger accounts, considerable information can be gleaned from it.

It is important that attention be called to the necessity of taking a monthly trial balance, inasmuch as there seems to be a disposition on the part of many bookkeepers to allow this matter to go unheeded. While the amount of the transactions per month when averaged over the 12 months of the year seems relatively small, the business of shipping fruit is a seasonal one and the total monthly business during the active months is proportionately large. The manager should insist that a balance of the accounts be secured not later than the second day of the following month. By posting at frequent intervals during the month, the amount of posting to be done at the end will comprise merely the closing entries and columnar totals of the books of original entry.

### RECEIPTS AND DISBURSEMENTS OF CASH.

A segregation of the receipts of cash for the month can easily be made from the cashbook, giving the total amounts received from the following sources: Fruit sales; cash sales of supplies; railroad claims; growers' accounts; accounts receivable (other than growers); miscellaneous.

A segregation of the disbursements of cash to show the total amounts paid out: To growers; for supplies; accounts payable; expense—general, packing-house, warehouse; miscellaneous.

A further division of the items grouped as miscellaneous under both receipts and disbursements of cash can be made if the amounts warrant and the information is desired.

## MONTHLY STATEMENTS.

### STATEMENT OF SALES.

To show the movement of supplies for the month the record of the sales can be shown in the following manner:

*Record of sales.*

| Item. | To growers. | To other customers. | Cash sales. | Total. |
|---|---|---|---|---|
| Arsenate of lead | | | | |
| Boxes | | | | |
| Paper | | | | |
| Nails | | | | |
| Gross sales | | | | |
| Less returns and allowances | | | | |
| Net sales | | | | |

### STATEMENT OF INDEBTEDNESS.

A statement of the indebtedness, segregated as to amounts due on notes and on open account, will be found of value in order to consider intelligently the proper financing of the business.

*Indebtedness.*

| Item. | Amount. | | Date due. |
|---|---|---|---|
| Notes payable in favor of— | | | |
| A | | | |
| B | | | |
| C | | | |
| Total | | | |
| Accounts payable owing to— | | | |
| D | | | |
| E | | | |
| F | | | |
| Total | | | |

### EXPENSES ITEMIZED.

Supplementing the information given in the statements of the disbursements of cash, in which the general, packing, and warehousing expenses appear in totals, a segregation of the same can be shown according to the accounts recommended in the paragraph entitled "Expense accounts" on page 22.

### RECORD OF SHIPMENTS.

Number of cars shipped during month ———. To date ———.

Number of cars on which money has been received during month ———.

Total amount ———.

Pools closed, date ———. Average prices ———.

The manager should include in his report a brief summary regarding other features of the operation of the business for examination by the directors.

## CLOSING THE BOOKS.

Preparatory to closing the books, an inventory should be taken of all supplies on hand, and this schedule should be written up in permanent form. With this should be included a schedule of expense items, such as postage, stationery and supplies on hand, and of the unconsumed balances of such accounts, as prepaid insurance and prepaid taxes.

The balances of all expense accounts and income accounts should be transferred to the profit-and-loss account in order to ascertain the net profit or loss for the season's operations, and this balance then should be transferred to the surplus account. After the books are closed and a post-closing trial balance has been taken to prove the mechanical accuracy of the work, the various financial and cost statements are made up for presentation to the members.

As a guide for the preparation of a financial statement, or balance sheet, to portray the condition of the business at the close of the year, the statement shown on page 29 is submitted.

*Financial statement at the close of business as of* ....................
(Date.)

| Assets. | | | Liabilities and capital. | |
|---|---|---|---|---|
| Land and buildings: | | | Bills payable | ............ |
| Land | ............ | | Accounts payable | ............ |
| Warehouse | ............ | | Warehouse building fund accumulations | |
| Packing-house | ............ | | Packing-house building fund accumulations | ............ |
| Spur track | ............ | | Undercharges | ............ |
| Total | ............ | | Accrued interest | ............ |
| Less reserve for depreciation | ............ | ............ | Capital and surplus: | |
| Equipment: | | | Capital stock or membership | ............ |
| Warehouse equipment | ............ | | Surplus: | |
| Packing-house equipment | ............ | | Balance as of previous year | |
| Office equipment | ............ | | Net profit for current year | ............ |
| Total | ............ | | | |
| Less reserve for depreciation | ............ | ............ | | |
| Inventory of supplies and merchandise: | | | | |
| Spray | ............ | | | |
| Boxes | ............ | | | |
| Paper | ............ | | | |
| Nails | ............ | | | |
| Merchandise | ............ | | | |
| Car-bracing lumber | ............ | ............ | | |
| Book accounts: | | | | |
| Growers' accounts | ............ | | | |
| Customers' accounts | ............ | | | |
| Total | ............ | | | |
| Less reserve for bad debts | ............ | ............ | | |
| Bills receivable | | ............ | | |
| Cash: | | | | |
| In bank | ............ | | | |
| On hand | ............ | ............ | | |
| Deferred charges: | | | | |
| Prepaid insurance | ............ | | | |
| Prepaid taxes | ............ | ............ | | |

A statement of revenue and expenditure is made up to show the revenue accruing to the business during the season and the expenditures which are chargeable against it:

*Statement of revenue and expenditure.*

REVENUE.

| | | |
|---|---|---|
| Profit on supplies | | |
| From warehouse operations | | |
| From packing-house operations | | |
| Interest on preharvest loans | | |
| Received on claims not apportioned | | |
| Total revenue | | |

EXPENDITURE.

| | | |
|---|---|---|
| Interest on loans | | |
| Expense: General (segregated as recommended in the paragraph under the caption "Expense accounts," p. 22) | | |
| Total expenditure | | |
| Net profit or loss | | |

## FILING THE RECORDS.

The selection of a system for filing the records of the business should have close attention so that the various records will be readily accessible. After the system is once adopted it should be adhered to strictly and the auxiliary records should be filed daily, or as often as they are entered in the books. Most of the forms in this system are loose leaf and are filed in binders. The charge tickets (Form 1), the journal vouchers (Form 27), and the checks (Form 30) are filed in numerical order. The truck tickets (Form 8), the loose-fruit receipts (Form 9), and the packed-fruit receipts (Form 11), are filed in a card file under the names of the growers in alphabetical order. The loading instructions (Form 14), the inspection reports (Form 16), the car reports (Form 17), the triplicate bills of lading, and all correspondence and memoranda pertaining to the shipments, are filed in the "car folders." For this purpose one unit of a vertical correspondence file can be used, a separate folder being devoted to the papers of each car. The tabs of the folders should show both the file numbers and the car numbers to facilitate reference.

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 1

## CHARGE TICKET.

Bought of

File No. ....

NAME..............................................

.............., 191...

MR..............................................

..............................................................

The supplies listed below are bought subject to the rules and regulations of the..................................................

| Quantity. | Items. | Amount. | |
|---|---|---|---|
| .......... | .......................................... | ........ | .... |
| .......... | .......................................... | ........ | .... |
| .......... | .......................................... | ........ | .... |
| .......... | .......................................... | ........ | .... |
| .......... | .......................................... | ........ | .... |
| .......... | .......................................... | ........ | .... |

I counted and received the above supplies.

....................................

Number .... Sold by..........................................

[Size of form, 7¼ by 4½ inches, exclusive of binding margin at top. Bind in pads of 50, alternating originals and duplicates; staple and perforate.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 2

## MERCANTILE LEDGER STATEMENT.

Sheet No. ....

Name....................................

................ 191..

Mr. ........................................

........................................

| Date. | Items. | Charge Tkt. No. | Debits. | Fol. | Credits. | Balance. |
|---|---|---|---|---|---|---|
| | | | | | | |
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[Size of form, 8½ by 11 inches, punched for ⅜-inch posts, 4¼ inches center to center.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 3

REQUISITION. No. ....

............ 191..

Mr. ..............................

..............................

Please deliver to..................................................

..................................................................

the following items only, and charge to our account.

Place number of this order on your bill.
Deliver no goods without an order.

| Quantity. | Description. |
|---|---|
| .......... | .................................................. |
| .......... | .................................................. |
| .......... | .................................................. |
| .......... | .................................................. |
| .......... | .................................................. |
| .......... | .................................................. |

Name........................................
Per.................................
Received..................................................
(Grower or employee.)

[Size of form, $8\frac{1}{2}$ by 5 inches, padded at top.]

---

U. S, Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 4

BOX MEMORANDUM, No. ....

Showing the Number of Boxes Returned to the Grower.

............ 191..

Delivered to.................................................

| Article. | Quantity. | Remarks. |
|---|---|---|
| New boxes.............. | ........ | .................... |
| Old boxes.............. | ........ | .................... |
| Tops, bundles.......... | ........ | .................... |
| Cleats, bundles........ | ........ | .................... |

Received from...............................................
Grower..........................................
Entered.......... Boxes delivered by.........................

[Size of form, $4\frac{1}{4}$ by $5\frac{1}{4}$ inches, exclusive of binding margin. In pads of 50, alternating originals and duplicates; staple and perforate.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 5

## BOX REGISTER.

Mr. ............................ ............ 191..
..............................

This is a statement (1) of the number of boxes containing loose fruit, and bundles of tops and cleats delivered by you to the packing house, as taken from the loose-fruit receipt, and (2) of the number of boxes whether empty or containing cull fruit, withdrawn by you from the packing house, as evidenced by the box memoranda to date.

*Recapitulation.*

| | New boxes. | Old boxes. | Tops. | Cleats. |
|---|---|---|---|---|
| Total boxes packed in central packing house | | | | |
| Add boxes withdrawn by the grower | | | | |
| Total | | | | |
| LESS boxes delivered by the grower | | | | |
| Number OVER or SHORT | | | | |
| Rate | | | | |
| Extension | | | | |

We have therefore {credited / charged} your account with the value of the above, amounting to $............

| Withdrawals. | | | | | | Deliveries. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date. | Box memorandum number. | New boxes. | Old boxes. | Tops, bdls. | Cleats, bdls. | Date. | Loose fruit receipt number. | Loose fruit in new boxes. | Loose fruit in old boxes. | Tops, bdls. | Cleats, bdls. |
| | | | | | | | | | | | |
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Kindly compare with your records, and advise us promptly in case there is a discrepancy.

[Size of form, 11 by 8½ inches, punched for ⅜-inch posts, 7 inches center to center.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 6

## CROP ESTIMATE.

Name ..................................

Grower ........................ ............... 191..

| Remarks. | Variety. | Boxes. |
|---|---|---|
| .......................... | Jonathan.............. | .......... |
| .......................... | Banana.............. | .......... |
| .......................... | Delicious.............. | .......... |
| .......................... | Esopus (Spitzenburg).. | .......... |
| .......................... | Rome Beauty.......... | .......... |
| .......................... | Stayman Winesap ..... | .......... |
| .......................... | Arkansas Black........ | .......... |
| .......................... | White Pearmain ....... | .......... |
| .......................... | Yellow Newtown ...... | .......... |
| .......................... | Winesap.............. | .......... |
| .......................... | Ben Davis............ | .......... |
| .......................... | Gano and Black Ben... | .......... |
| .......................... | Grimes ............... | .......... |
| .......................... | Ortley............... | .......... |
| .......................... | ..................... | .......... |
| .......................... | ..................... | .......... |
| .......................... | ..................... | .......... |
| .......................... | ..................... | .......... |
| .......................... | ..................... | .......... |

I hereby certify that the foregoing is a true and conservative estimate of my crop.

Grower..................................................

Entered.......... Estimated by...................................

[Size of form, 7¼ by 4¼ inches, punched for ring binder.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 7

## ESTIMATE AND ORDER REGISTER.

Register of Orders Accepted and Shipments Tramped.

Variety............................

| Date. | | Order No. | File No. | Consignee. | Destination. | Extra fancy. | | | Fancy. | | | "C" grade. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 36–125<br>36–88 [a] | 138–163<br>96–125 | 175 & SM<br>138 & SM | 36–125<br>36–88 | 138–163<br>96–125 | 175 & SM<br>138 & SM | 36–163 | 175 & SM |
| | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | |

[a] The above division of sizes pertains to Delicious, Banana, and Rome Beauty only.

[Size of form 11¼ by 11⅞ inches, punched for ⅜-inch posts, 7 inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 7

# ESTIMATE AND ORDER REGISTER.

## REGISTER OF GROWERS' ESTIMATES.

*Percentage key.*

| | | | |
|---|---|---|---|
| Grade...... | ............ | ............ | ............ |
| Size...... | ............ | ............ | ............ |

Variety..........................

| Grower. | Estimate. | Date. | Unsold balances. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Extra fancy. | | | Fancy. | | | "C" grade. | |
| | | | 36–125<br>36–88 [a] | 138–163<br>96–125 | 175 & SM<br>138 & SM | 36–125<br>36–88 | 138–163<br>96–125 | 175 & SM<br>138 & SM | 36–163 | 175 & SM |
| | | | | | | | | | | |
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[a] The above size division pertains to Delicious, Banana, and Rome Beauty only.

[This form is printed on the reverse side of Form No. 7, p. 36.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 8

No. ....

## TRUCK TICKET.

Received on ............. 191..

account of..............................................................

This ticket serves merely as a memorandum of the following fruit to be delivered to the packing house of the..............................................................

Upon arrival at the packing house a loose-fruit receipt will be issued.

| No. boxes. | Variety. | Remarks. |
|---|---|---|
| .......... | .................................... | .................................... |
| .......... | .................................... | .................................... |
|  | Total number boxes. |  |

..............................
(Driver.)

[Size of form, 3¾ by 5 inches, exclusive of binding margin. In pads of 50, alternating originals, duplicates, and triplicates.]

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U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 9

No. ....

## LOOSE-FRUIT RECEIPT.

Name.....................................

Received on

account of..............................................................

The following is received in open boxes, as is for packing without guaranty from the undersigned as to the variety, quality, or weight of the fruit.

| New boxes. | Old boxes. | Variety |  | Tally. |  |  |
|---|---|---|---|---|---|---|
| .......... | .......... | .................................... | .......... | .......... | .......... | .......... |
| .......... | .......... | .................................... | .......... | .......... | .......... | .......... |
| .......... | .......... | .................................... | .......... | .......... | .......... | .......... |
|  |  | Total No. boxes.................. | .......... | .......... | .......... | .......... |
| Tops, bdls. |  | Cleats, bdls. | .......... | .......... | .......... | .......... |
| Name........................................ |  |  | .......... | .......... | .......... | .......... |
| Per........................................ |  |  | .......... | .......... | .......... | .......... |
| Entered.......................... | Truck ticket No.......... |  | .......... | .......... | .......... | .......... |

[Size of form, 4¼ by 5¼ inches. In pads of 25, alternating originals, duplicates, and triplicates.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM No. 10

## TALLY SHEET.

Variety.............................. Date ............

| | Extra fancy. | | | Fancy. | | | "C" grade. | |
|---|---|---|---|---|---|---|---|---|
| | 36–125<br>36–88.[a] | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–163. | 175 & Sm. |
| Grower. | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Packed-fruit receipt No...... | | | | | | | | |
| Total........................... | | | | | | | | |
| Grower. | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Packed-fruit receipt No. .... | | | | | | | | |
| Total........................... | | | | | | | | |
| Grower. | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Packed-fruit receipt No. .... | | | | | | | | |
| Total........................... | | | | | | | | |
| Grower. | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Packed-fruit receipt No. .... | | | | | | | | |
| Total........................... | | | | | | | | |
| Grower. | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| Packed-fruit receipt No. .... | | | | | | | | |
| Total........................... | | | | | | | | |
| Grand total.... | | | | | | | | |

[a] The above division of sizes pertains to Delicious, Banana, and Rome Beauty only.

Receiving clerk ........................ Receipts written by ......................

[Size of form, 13¾ by 10¾ inches, punched at top for $\frac{5}{16}$-inch posts, 8½ inches from center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 11

No. ....

## PACKED-FRUIT RECEIPT.

............ 191..

Received on
account of..............................................................

This receipt is not negotiable.

Except by special agreement, all fruit handled for growers' account will be pooled.

IMPORTANT: Please examine this receipt carefully; in case of error have same rectified at once.

| | Extra fancy. | | | Fancy. | | | "C" grade. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variety. | 36–125<br>36–88.[a] | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–163. | 175 & Sm. | | | |
| .............. | ......... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ...... | ...... | ...... |
| .............. | ......... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ...... | ...... | ...... |
| .............. | ......... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ...... | ...... | ...... |
| .............. | ......... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ...... | ...... | ...... |
| .............. | ......... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ...... | ...... | ...... |
| .............. | ......... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ...... | ...... | ...... |
| Total.... | ......... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ...... | ...... | ...... |

[a] The above division of sizes pertains to Delicious, Banana, and Rome Beauty only.

Entered by.......................... Per..................................

[Size of form, 5½ by 8¾ inches, exclusive of binding margin. In pads of 50, alternating originals and duplicate; staple and perforate.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 12

## REGISTER OF PACKED FRUIT RECEIPTS.

Received on
account of..............................................................

| Date. | Receipt number. | Extra fancy. | | | Fancy. | | | "C" grade. | | Extra fancy. | | | Fancy. | | | "C" grade. | | Extra fancy. | | | Fancy. | | | "C" grade. | | ✓ | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 36–125<br>36–88.[a] | 138–163<br>96–125. | 175 &Sm.<br>138 &Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 &Sm.<br>138 &Sm. | 36–163. | 175 & Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 &Sm.<br>138 &Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 &Sm.<br>138 &Sm. | 36–163. | 175 & Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 &Sm.<br>138 &Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 &Sm.<br>138 &Sm. | 36–163. | 175 & Sm. | | |
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[a] The above division of sizes pertains to Delicious, Banana, and Rome Beauty only.

[Size of form $11\frac{1}{4}$ by $13\frac{7}{8}$ inches, punched for $\frac{5}{16}$-inch posts, $8\frac{1}{4}$ inches center to center.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 13.

## RECONCILEMENT OF FRUIT DELIVERIES.

.................... 191..

Mr. ........................................
........................................

Below is a statement of the total number of boxes of the different varieties of fruit delivered by you to date, as shown by our records. To obviate clerical work entailed in rectifying errors, which might be found after the pools have been made up, we are submitting our records of receipts, for your information. Kindly make a careful comparison of these figures with your record and if correct please sign and return. In case a discrepancy is found kindly bring in your duplicate receipts to the office for final checking.

FAILURE TO NOTIFY US ON OR BEFORE ...................., 191.., WILL BE TAKEN AS AN ACKNOWLEDGMENT OF YOUR AGREEMENT AS TO THE CORRECTNESS OF THE FOLLOWING FIGURES:

| Variety. | Extra fancy. | | | Fancy. | | | "C" grade. | | | | | ✓ | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 36–125<br>36–88.[a] | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–163. | 175 & Sm. | | | | | |
| | | | | | | | | | | | | | |
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The foregoing is a correct statement of the fruit delivered on account of the undersigned to the ........................................

Signed ........................................

[a] The above division of sizes pertains to Delicious, Banana, and Rome Beauty only.

[Size of form, $8\frac{1}{2}$ by 11 inches, punched for $\frac{3}{8}$-inch posts, $4\frac{1}{4}$ inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 14

## LOADING INSTRUCTIONS.

Load the car according to the following instructions.

Return this sheet to the office with the car checker's record.

Order number.................. Date order received..............

Date order confirmed............ Date to be loaded................

| Number boxes. | Variety. | Extra fancy. | Fancy. | "C" grade. | Sizes. |
|---|---|---|---|---|---|
| .......... | .................. | .......... | .......... | .......... | .................... |
| .......... | .................. | .......... | .......... | .......... | .................... |
| .......... | .................. | .......... | .......... | .......... | .................... |
| .......... | .................. | .......... | .......... | .......... | .................... |
| .......... | .................. | .......... | .......... | .......... | .................... |
| .......... | .................. | .......... | .......... | .......... | .................... |

Loaded in

Car number............ Date.......191..

[Size of form, 8½ by 6 inches, pad at top.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 15

## CAR CHECKER'S RECORD.

Loaded by..............................

Checked by..............................

Manifested by..............................

Date.............................., 191..

Car file number..........

Car initial number..........

..........End.

..........End.

| Variety. | Grade. | Car tier. | 64's & larger. | 72 | 80 | 88 | 96 | 104 | 113 | 125 | 138 | 150 | 163 | 175 | 188 | 200 | 216 | Variety. | Grade. | Car tier. | 64's & larger. | 72 | 80 | 88 | 96 | 104 | 113 | 125 | 138 | 150 | 163 | 175 | 188 | 200 | 216 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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[Size of form, $10\frac{1}{4}$ by 16 inches, punched for $\frac{3}{8}$-inch posts, 6 inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 16

## INSPECTION REPORT.

.........................................

Report of the grading, packing, and general condition of fruit contained in car No. ......... Loaded at.............................. Date............., 191..

---

Color of fruit.......................................................................

Condition...........................................................................

Merits as a whole................................................................

Defects as a whole...............................................................

Had fruit been inspected previously?..........................................

If grower's pack, was each lot rigidly inspected?..........................

Grading and packing.............................................................

Diagonal or straight..............................................................

Bulge................................ Inches.......................................

What grades are wrapped?......................................................

Printed or plain wrapper.........................................................

Are boxes labeled?...................... Brand.....................................

Are box ends printed?............................................................

Are boxes clean?..................................................................

.......................................

Per.......................................
(Inspector.)

[Size of form, 8½ by 5½ inches, pad at top.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 17

## CAR REPORT.

..........................................

..........................................

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### ORDER AND BILLING RECORD.

Loading point.............................................. Car No. ..........

Date car ordered............ Hour....... Date to be placed..... Hour.......

Ordered iced or vent..............................................................

Date spotted............... Hour....... Date forwarded....... Hour.......

Date billed................. Hour..............................................

### LOADING REPORT.

Began loading.............. Hour....... Finished............... Hour.......

Was car carefully examined for defects?.............................................

State defects found in floors, doors, ice tanks, plugs, etc..............................

..................................................................................

Quantity of ice in tanks when spotted, brake end............... Rear end.........

Quantity of ice in tanks when forwarded, brake end............ Rear end.........

While loading, were plugs in or out?............ Vents opened or closed?..........

When forwarded, were plugs in or out?......... Vents opened or closed?..........

Was standard stripping and bracing used?............................................

Was loading delayed?.................... Why?.......................................

### GENERAL CONDITIONS.

Condition of weather when car was loaded.............................................

Temperature in warehouse while loading car..........................................

.....................................

Per.....................................

[Size of form, 8½ by 5½ inches, pad at top.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 18

## MANIFEST.

............., 191..

Loaded at ..............................
Shipped to ..............................

........................................

Car file No. ........ Car No. ........ Routing.................. Iced / Vent ........

| Variety. | Grade. | 64's and larger. | 72 80 88 | 96 104 113 125 | 138 150 163 | 175 188 200 | Total. |
|---|---|---|---|---|---|---|---|
| ............... | ....... | ....... | ............... | ....................... | ............... | ............... | ....... |
| ............... | ....... | ....... | ............... | ....................... | ............... | ............... | ....... |
| ............... | ....... | ....... | ............... | ....................... | ............... | ............... | ....... |
| ............... | ....... | ....... | ............... | ....................... | ............... | ............... | ....... |
| ............... | ....... | ....... | ............... | ....................... | ............... | ............... | ....... |
| ............... | ....... | ....... | ............... | ....................... | ............... | ............... | ....... |

[Size of form, 7¼ by 8½ inches, pad at top.]

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U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 19

## INVOICE.

............., 191..

Mr. ..............................

..............................

Bought of

........................................

Terms........

| | | | | |
|---|---|---|---|---|
| ............................................ | ............ | ....... | ............ | ....... |
| ............................................ | ............ | ....... | ............ | ....... |
| ............................................ | ............ | ....... | ............ | ....... |
| ............................................ | ............ | ....... | ............ | ....... |
| ............................................ | ............ | ....... | ............ | ....... |
| ............................................ | ............ | ....... | ............ | ....... |

[Size of form, 6½ by 7¼ inches, pad at top.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 20

## POOL SHEET.

Variety........................

| Date of shipment. | Car file number. | Car number. | Grades shipped. | | | | Total number boxes. | Date returns entered. | J. V. | Amount realized. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Extra fancy. | Fancy. | "C." | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Footings ford. | | | | | | | | | | |
| Totals. | | | | | | | | | | |

| Journal distribution. | Debits. | Credits. |
|---|---|---|
| Fruit returns | | |
| Warehouse revenue | | |
| Inspection revenue | | |
| Labeling revenue | | |
| Sundry growers | | |
| Overage and underage a/c | | |
| Total | | |

Pool clerk........................

Approved........................ J. V.

| Deductions. | | | | |
|---|---|---|---|---|
| Date. | J. V. | File No. | Car number. | Amount. |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Actual net value of pool. | | | | |

[Size of form, 11¼ by 11⅞ inches, punched for ⅜-inch posts, 7 inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 20A

## POOL SHEET.

Variety........................

| Date of shipment. | Car file No. | Car number. | Total number boxes. | Amount realized. | J. V. | Net returns. | | | | | | | | Date returns entered. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Extra fancy. | | Fancy. | | "C" grade. | | | | |
| | | | | | | Boxes. | Amount. | Boxes. | Amount. | Boxes. | Amount. | Boxes. | Amount. | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | |
| Footings ford. | | | | | | | | | | | | | | |
| Totals. | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | Deductions. |
| | | | | | | | | | | | | | | Net gr. value. |

| Deductions. | | | | |
|---|---|---|---|---|
| J. F. | Ex. fcy. | Fancy. | "C" grade. | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| Total. | | | | |
| Actual value of pool. | | | | |

| Journal distribution. | Debits. | Credits. | |
|---|---|---|---|
| Fruit returns | | | J. V. No. |
| Warehouse revenue | | | Pool clerk |
| Inspection revenue | | | Approved by |
| Labeling | | | |
| Sundry growers | | | |
| Overage and underage a/c | | | |
| Total | | | |

[Size of form, $11\frac{1}{4}$ by $11\frac{7}{8}$ inches, punched for $\frac{3}{8}$-inch posts, 7 inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 21

## UNIFORM ACCOUNT SALES.

Adopted under the provisions of the uniform contract of the Fruit Growers' Agency, Inc.

File
Acc't .
Sales No. ....
........................., 191..

..............................
..............................

| | Ex. fancy. | | Fancy. | | "C" grade. | | | |
|---|---|---|---|---|---|---|---|---|
| Total number of boxes in this pool.................. | | | | | | | | |
| Gross realized values F. O. B.................... | | | | | | | | |
| DEDUCTIONS. | | | | | | | | |
| Warehouse charges ......................per box.. | | | | | | | | |
| Inspection charges........................per box.. | | | | | | | | |
| Labeling charges..........................per box.. | | | | | | | | |
| ................................................ | | | | | | | | |
| ................................................ | | | | | | | | |
| Less total charges.................................... | | | | | | | | |
| Net amount of returns to growers.................. | | | | | | | | |

DISTRIBUTION OF RETURNS TO THE GROWER ON .................. VARIETY.

| Extra fancy. | | | Fancy. | | | "C" grade. | | Net average price. | Net amount. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 36–125<br>36–88.[a] | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–163. | 175 & Sm. | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | Net amount credited to your account...... | | |

[a] Above size divisions pertain to Delicious, Banana, and Rome Beauty only.

NOTE.—We are to-day crediting your account with the net amount of this Account Sales which is a report of results on the pool as shown above. The amount credited to your account is the amount indicated as "Net amount credited to your account." Only such charges as clearly constitute a deduction from the net results to the growers are shown here as "Deductions." Other charges, such as "Packing" and "Reserve Fund," which are either an actual orchard expense, or a permanent investment, are not classified, but will be shown on your statement of account, which will be rendered on another form.

Keep this account sales to check off the credits on your statement.

[Size of form, 11 by 8½ inches, punched for $\frac{3}{16}$-inch posts, 7 inches center to center.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 22

## FRUIT LEDGER STATEMENT.

Sheet No. ....

............., 191..

..............................

....................

IN ACCOUNT WITH..........................

Note: Retain this statement for future reference. In case of error return at once for correction.

| Date. | Charges. | Folio. | Amount debited. | Date. | This column for credits other than fruit returns. | This column for name of variety or pool. | Folio. | Acc't sales No. | Amount credited |
|---|---|---|---|---|---|---|---|---|---|
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[Size of form, 8½ by 11 inches, punched for ⅝-inch posts, 4¼ inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 23

## INVENTORY SHEET.

Variety..............................

| Date. | Item. | Extra fancy. | | | Fancy. | | | "C" grade. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 36–125<br>36–88.[a] | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–125<br>36–88. | 138–163<br>96–125. | 175 & Sm.<br>138 & Sm. | 36–163. | 175 & Sm. | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |
| | Balance | | | | | | | | | | | |
| | Receipts | | | | | | | | | | | |
| | Total | | | | | | | | | | | |
| | Shipments | | | | | | | | | | | |

[a] The above size division pertains to Banana, Rome Beauty, and Delicious only.

Inventory Clerk..............................

[Size of form, 11¼ by 11⅞ inches, punched for ⅜-inch posts, 7 inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 24

## REGISTER OF ORDERS ON ACCOUNT.

For the season of 191........................................

| Order number. | Date accepted. | | Drawer. | Payee. | Address. | Amount. | | Payments applied. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | J. V. | Date. | | Amount. | |
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[Size of form, 11¼ by 11⅝ inches, punched for ⅜-inch posts, 7 inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM No. 25

Journal voucher number........

Date of advance

## SCHEDULE OF ADVANCES ON FRUIT TO GROWERS.

DISTRIBUTION SHEET.

| Variety. | Group 1. | Group 2. |
|---|---|---|
| | .......... | .......... |
| | .......... | .......... |
| | .......... | .......... |

Sheet No. ....

| Grower. | Grower's debit balance. | Equalizing advance. | | | | Variety advance. | | | | Total variety plus equalizing advance. | Amount to be applied on growers' notes. | Amount of payments on orders and crop mortgages. | Check numbers. | Amount of checks to growers. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of boxes. | Amount of credit at average rate per box. | Credit less debit balance. | O. D. in excess of advance credit. | Extra fancy. Rate G1............ Rate G2............ | | Fancy. Rate G1............ Rate G2............ | | | | | | |
| | | | | | | Boxes. | Amount. | Boxes. | Amount. | | | | | |
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[Size of form $11\frac{1}{4}$ by $13\frac{7}{8}$ inches, punched for $\frac{5}{16}$-inch posts, $8\frac{1}{4}$ inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 26

## CASH JOURNAL.

Credit.

| Cash. | Journal voucher number. | Check number. | Bank withdrawals. | ✓ | General ledger. | Folio. | Mercantile ledger. | Fruit ledger. | Sales. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Boxes. | Paper. | Nails. | Spray. | Fruit. | Mdse. | |
| | | | | | | | | | | | | | | | |
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[Size of form, $11\frac{1}{4}$ by $13\frac{7}{8}$ inches, punched for $\frac{5}{16}$-inch posts, $8\frac{1}{4}$ inches center to center.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 26

## CASH JOURNAL.

Debit.

|  | Mdse. | Fruit returns. | Fruit ledger. | Mercantile ledger. | General ledger. | Ledger folio. | Bank deposits. | Cash. | Date. | Items. |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Balance brought forward. |
|  |  |  |  |  |  |  |  |  |  |  |
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[This form is printed on the reverse side of the form shown on p. 55.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 27

## JOURNAL ENTRY VOUCHER.

Attach invoice here.

| | Debit. | | Credit. | |
|---|---|---|---|---|
| Dr. ........ | | | | |
| | | | | |
| Cr. ........ | | | | |
| | | | | |

| Date. | | Items. | | | | |
|---|---|---|---|---|---|---|
| | | For: | | | | |
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| | | | | | | |

Received payment in full of above account.

........................................Dollars........

$............ ..................................................

[Size of form, 8½ by 8½ inches, pad at top.]

Voucher No. ......

Check No. ...... Amount, $..........

Check drawn in favor of ......................

| | | |
|---|---|---|
| Debits: | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| Credits: | | |
| | | |
| | | |
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| | | |

Vouchered and entered: J. F.

..................................................

Approved:

..................................................

[This form is printed on the reverse side of Form 27.]

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF MARKETS
UNIFORM ACCOUNTING SYSTEM
FRUIT SHIPPING FORM NO. 31

## LABOR DISTRIBUTION SHEET.

Name........................................................................ No. .......

| Date. | | Total hours. | Packing house. | | | | | | | | Handling supplies. | Warehouse. | | | | | | Office. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Foreman, clerks. | Receiving. | Sorting. | Floor work. | Packing. | Pressing. | Miscellaneous. | | | Foreman, clerks. | Trucking. | Car loading. | Labeling. | Miscellaneous. | | |
| 1 | 16 | | | | | | | | | | | | | | | | | |
| 2 | 17 | | | | | | | | | | | | | | | | | |
| 3 | 18 | | | | | | | | | | | | | | | | | |
| 4 | 19 | | | | | | | | | | | | | | | | | |
| 5 | 20 | | | | | | | | | | | | | | | | | |
| 6 | 21 | | | | | | | | | | | | | | | | | |
| 7 | 22 | | | | | | | | | | | | | | | | | |
| 8 | 23 | | | | | | | | | | | | | | | | | |
| 9 | 24 | | | | | | | | | | | | | | | | | |
| 10 | 25 | | | | | | | | | | | | | | | | | |
| 11 | 26 | | | | | | | | | | | | | | | | | |
| 12 | 27 | | | | | | | | | | | | | | | | | |
| 13 | 28 | | | | | | | | | | | | | | | | | |
| 14 | 29 | | | | | | | | | | | | | | | | | |
| 15 | 30 | | | | | | | | | | | | | | | | | |
| | 31 | | | | | | | | | | | | | | | | | |
| Total..... | | | | | | | | | | | | | | | | | | |

From.................................................. To..................................................

Timekeeper..................................................

[Size of form, 8½ by 5½ inches, pad at top].

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 32

# PAY ROLL.

Pay roll No. ....

Sheet No. ......

From.............................. To..................................

| Employee's name. | Packing house. | | | | | | | | Handling supplies. | Warehouse. | | | | | | Office. | Total hours. | Rate. | Amount. | | | Em-ployee's number. | Check number. | | Employee's receipt. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Foreman, clerks. | Receiving. | Sorting. | Floor work. | Packing. | Pressing. | Miscellaneous. | | | Foreman, clerks. | Trucking. | Car loading. | Labeling. | Miscellaneous. | | | | | | | | | | | |
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[Size of form, 10¼ by 16 inches, punched for ⅜-inch posts, 6 inches center to center.]

U. S. Department of Agriculture
Bureau of Markets
Uniform Accounting System
Fruit Shipping Form No. 32

## JOURNAL DISTRIBUTION.

Journal voucher No. ......

| | Debits. | | Credits. | |
|---|---|---|---|---|
| PACKING HOUSE. | | | | |
| Foreman and clerks | | | | |
| Receiving | | | | |
| Sorting | | | | |
| Floor work | | | | |
| Packing | | | | |
| Pressing | | | | |
| Miscellaneous | | | | |
| | | | | |
| Handling supplies | | | | |
| WAREHOUSE. | | | | |
| Foreman and clerks | | | | |
| Trucking | | | | |
| Car loading | | | | |
| Labeling | | | | |
| Miscellaneous | | | | |
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| Office | | | | |
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**BULLETIN No. 591**

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**CHARLES J. BRAND, Chief**

**Washington, D. C.** **PROFESSIONAL PAPER** **December 26, 1917**

# MANUFACTURING TESTS OF THE OFFICIAL COTTON STANDARDS FOR GRADE.

By William S. Dean, *Assistant in Cotton Testing*, and Fred Taylor, *Cotton Technologist.*

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## INTRODUCTION.

The spinning tests herein described[1] were conducted for the purpose of determining the relative intrinsic values of cotton of the grades of Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary.

The principal factors considered in making the tests were: (1) The percentage of waste; (2) the tensile strength of the yarn; (3) the bleaching properties of the yarn and cloth; (4) the moisture content; and (5) other manufacturing properties of the cotton.

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[1] The cotton was purchased by Messrs. D. E. Earle, D. C. Griffith, W. C. Neale, and Hal Brown, cotton specialists. The grading was done by the board of examiners (a committee authorized to hear disputes under the provisions of the U. S. cotton futures Act). The tests, spinning and weaving, were conducted in representative mills at Fall River, Mass., and in the textile department of the North Carolina State College of Agriculture and Engineering, West Raleigh, N. C., under the general supervision of Fred Taylor, cotton technologist, and D. E. Earle, specialist in cotton classing, and were made by William S. Dean, assisted by George H. Anderson, assistant in cotton classing, and Messrs. J. J. W. Cooper, C. E. Coburn, C. E. Killingsworth, R. V. Hellams, and H. B. Richardson, assistants in agricultural technology. The bleaching tests were made by W. S. Dean and Prof. Everett H. Hinckley, in charge of chemistry, New Bedford Textile School, New Bedford, Mass., at bleacheries in Fall River and in the New Bedford Textile School.

Note.—This bulletin should be of interest to cotton producers, manufacturers, and dealers.

## ORIGIN OF THE COTTON.

Cotton of each grade, approximately $\frac{15}{16}$ inch to 1 inch in length of staple, was purchased from the following zones or sections of the cotton belt: Piedmont Plateau, Atlantic Coastal Plains, eastern Gulf Coastal Plains, western Gulf Coastal Plains, and the western Prairie Lands and Plateau. These zones, or sections, are recognized as producing cotton of different character, largely because of differences in soil or of climatic conditions.

The cotton used was from the 1914 crop and was purchased during the months of May and June, 1915. The Middling Fair cotton was slightly below the standard grade, suitable cotton of that grade not being on the market at the time of purchase.

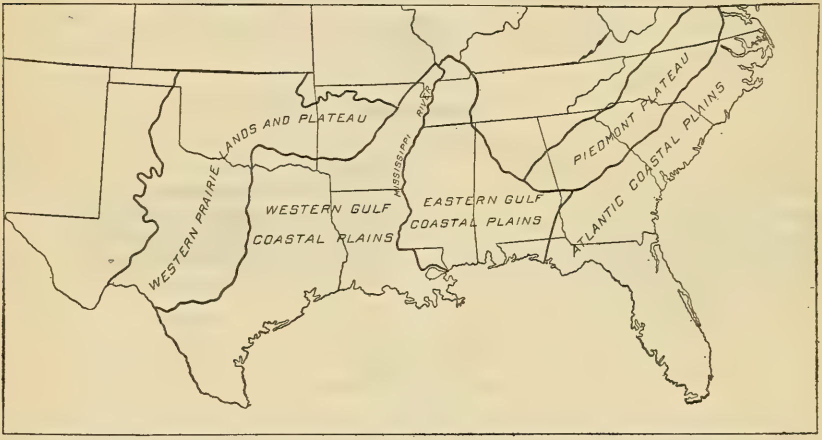

WESTERN PRAIRIE LANDS AND PLATEAU
MISSISSIPPI RIVER
WESTERN GULF COASTAL PLAINS
EASTERN GULF COASTAL PLAINS
PIEDMONT PLATEAU
ATLANTIC COASTAL PLAINS

FIG. 1.—Map showing the different zones from which cotton used in the tests was purchased.

Samples were taken from 12 different parts of each bale and graded by members of the board of examiners, a committee authorized to hear disputes under the provisions of the United States cotton futures Act, and rejections were made of bales not uniform in grade and staple.

## SPINNING TESTS AT COTTON MILL.

The upland cotton produced east of the Mississippi River and that produced west of the Mississippi (see fig. 1) were tested separately by grades in a cotton mill in Fall River, Mass.

### METHODS OF COMPARISON.

The bales of cotton representing the five grades were weighed carefully on the same day, and these weights, less the weight of tare, were used as the basis of calculations in making the spinning tests. In each case the different bales of cotton of the same grade were mixed thoroughly. The cotton was run through a bale breaker and then through an air pipe, which conveyed it a distance of approximately 200 feet, where it was deposited in a large pile. Invariably this was done late in the afternoon, and the loose cotton was left in this condition over night.

While the cotton was passing through the breaker and finisher pickers and cards total weights of the stock were obtained after each process on scales sensitive to half an ounce. The different grades were run through the same machines and subjected to the same speeds, settings, drafts, etc., throughout all the manufacturing processes, subject to such changes as were necessary to maintain a correct weight of the stock. The cards were stripped at regular intervals in conformity with the best mill practices. There was no intermediate process of doubling in the picker room; therefore three processes of drawings were used. The bands, spindles, rolls, etc., on the spinning frame were examined carefully in order to eliminate in so far as possible such mechanical defects as would tend to reduce or vary the quality of the product.

Table I gives the organizations of the machines used in the manufacture of 22's yarn.

TABLE I.—*Organization of machinery for 22's yarn.*

| Machine. | Actual draft. | Doubling. | Size. | Twist per inch. |
|---|---|---|---|---|
| Pickers: | | | | |
| Bale breaker— | | | | |
| Opener and breaker (combined) | | | 16-oz. lap | |
| Finisher | 4.50 | 4 | 13½-oz. lap | |
| Cards | 99.65 | 1 | 56 grains | |
| Drawing frames: | | | | |
| First drawing | 5.38 | 6 | 62.5 grains | |
| Second drawing | 5.43 | 6 | 69 grains | |
| Third drawing | 5.52 | 6 | 75 grains | |
| Fly frames: | | | | |
| Slubber | 4.5 | 1 | 0.5 hank roving. | 0.85 |
| Intermediate | 5.60 | 2 | 1.40 hank roving. | 1.42 |
| Fine | 6.28 | 2 | 4.4 hank roving. | 2.51 |
| Spinning: | | | | |
| Ring frame | 10 | 2 | 22 | 22.23 warp. |
| Ring frame | 10 | 2 | 22 | 17.50 filling. |

## WASTE PERCENTAGES.

The percentages of waste discarded in the manufacturing processes from each of the five grades of cotton of both the eastern and western upland lots are found in Table II. These percentages were computed in the following manner: The waste discarded at each machine was considered as being a certain percentage of the net amount of cotton fed into that machine, but the total percentages as given "through the card" were based on the net amount of cotton fed into the first waste-cleaning machine. The tare on the bales was not included in these calculations.

TABLE II.—*Waste percentages of different grades of Eastern Upland and Western Upland cotton (mill tests).*

|  |  | Eastern stock. |  |  |  |  | Western stock. |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | M. F.[1] | G. M. | M. | L. M. | G. O. | M. F. | G. M. | M. | L. M. | G. O. |
| Net weight fed to picker | pounds.. | 2,810.00 | 3,950.50 | 4,586.12 | 5,075.38 | 5,386.63 | 2,223.00 | 4,965.00 | 4,662.37 | 4,238.87 | 5,317.44 |
| *Machines.* | *Kinds of waste.* |  |  |  |  |  |  |  |  |  |  |
| Pickers | Visible: |  |  |  |  |  |  |  |  |  |  |
|  | Opener, motes and fly | 0.16 | 0.32 | 0.59 | 0.69 | 1.29 | 0.27 | 0.31 | 0.63 | 0.88 | 1.32 |
|  | Breaker, motes and fly | .20 | .31 | .45 | .71 | 1.02 | .22 | .32 | .51 | .71 | 1.10 |
|  | Finisher, motes and fly | .42 | .50 | .83 | 1.05 | 1.56 | .37 | .52 | .91 | 1.28 | 1.75 |
|  | Total visible | .78 | 1.13 | 1.87 | 2.45 | 3.87 | .86 | 1.15 | 2.05 | 2.87 | 4.17 |
|  | Invisible | 3.18 | 3.03 | 3.53 | 4.22 | 5.08 | 3.06 | 3.40 | 3.74 | 4.03 | 4.66 |
|  | Total visible and invisible | 3.96 | 4.16 | 5.40 | 6.67 | 8.95 | 3.92 | 4.55 | 5.79 | 6.90 | 8.83 |
| Cards[2] | Visible: |  |  |  |  |  |  |  |  |  |  |
|  | Flat strippings | 2.36 | 2.51 | 2.71 | 2.66 | 2.96 | 2.34 | 2.55 | 2.67 | 2.93 | 3.31 |
|  | Cylinder and doffer strippings | .45 | .41 | .51 | .52 | .54 | .34 | .45 | .51 | .55 | .60 |
|  | Motes and fly | 1.07 | 1.24 | 1.80 | 2.12 | 2.99 | 1.06 | 1.27 | 1.82 | 2.44 | 3.58 |
|  | Sweepings | .16 | .10 | .16 | .20 | .32 | .11 | .20 | .18 | .30 | .29 |
|  | Total visible | 4.04 | 4.26 | 5.18 | 5.50 | 6.81 | 3.85 | 4.47 | 5.18 | 6.22 | 7.78 |
|  | Invisible | .83 | .52 | .38 | .46 | .53 | .63 | .55 | .85 | .73 | 1.06 |
|  | Total visible and invisible | 4.87 | 4.78 | 5.56 | 5.96 | 7.34 | 4.48 | 5.02 | 6.03 | 6.95 | 8.84 |
| Pickers and cards[3] | Visible | 4.66 | 5.21 | 6.77 | 7.58 | 10.08 | 4.56 | 5.42 | 6.93 | 8.66 | 11.26 |
|  | Invisible | 3.97 | 3.54 | 3.89 | 4.65 | 5.56 | 3.66 | 3.93 | 4.54 | 4.71 | 5.63 |
|  | Total visible and invisble | 8.63 | 8.75 | 10.66 | 12.23 | 15.64 | 8.22 | 9.35 | 11.47 | 13.37 | 16.89 |

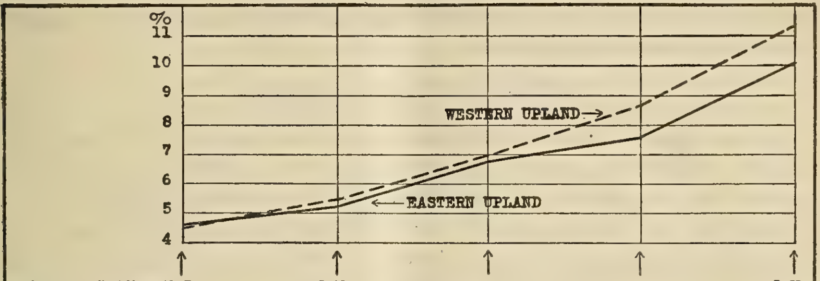
---

[1] The grades of cotton are indicated in the tables of this bulletin as follows: M. F. = Middling Fair; G. M. = Good Middling; M. = Middling; L. M. = Low Middling. G. O. = Good Ordinary.

[2] Based on net weight fed to cards.

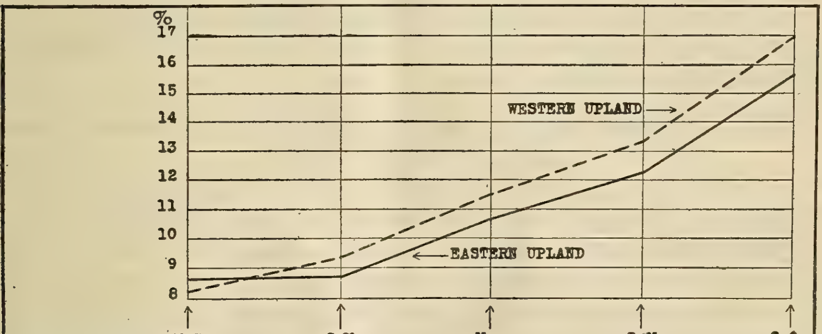
[3] Based on net weight fed to pickers.

A study of Table II shows a close relationship between the percentages of waste discarded in the manufacturing processes and the corresponding grades of cotton. The percentages of waste increase consistently as the grades of the cotton decrease in quality from Midling Fair to Good Ordinary. The amount of invisible waste is comparatively regular, indicating uniformity in the moisture content of the cotton while it was being manufactured. In the manufacture of western upland cotton a somewhat increased amount of waste, as compared with the corresponding grades of eastern upland cotton, was discarded. However, these figures are not conclusive because they indicate the results obtained from the crop of only one year.



| KIND OF STOCK | M.F. | G.M. | M. | L.M. | G.M. |
|---|---|---|---|---|---|
| EASTERN UPLAND | 4.66 | 5.21 | 6.77 | 7.58 | 10.08 |
| WESTERN UPLAND | 4.56 | 5.42 | 6.93 | 8.66 | 11.26 |

FIG. 2.—Visible waste percentage of five grades of both Eastern Upland and Western Upland cotton. (Mill tests.)



| KIND OF STOCK | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| EASTERN UPLAND | 8.63 | 8.75 | 10.66 | 12.23 | 15.64 |
| WESTERN UPLAND | 8.22 | 9.35 | 11.47 | 13.37 | 16.89 |

FIG. 3.—Combined visible and invisible waste percentages of five grades of both Eastern Upland and Western Upland cotton. (Mill tests.)

Figure 2 represents graphically the total visible waste percentages of the five grades of both eastern upland and western upland cotton. The combined visible and invisible waste percentages of the five grades of eastern upland and western upland cotton are represented graphically in figure 3. The figures given in the table below each graph were taken from Table II and placed in this position for convenient reference. The close relationship between the cotton from the two sections of the cotton belt and the relationship between the grade and the percentage of waste are apparent.

It should be borne in mind that the greater part of the cotton taken out as waste has a commercial value, since it is used in various branches of the waste industry.

### TENSILE-STRENGTH COMPARISONS.

In order to test the yarn produced from each grade of cotton under uniform conditions, tensile-strength tests were conducted in the laboratory of the Bureau of Markets, United States Department of Agriculture, at Washington, D. C. Cotton is hygroscopic, and any change in atmospheric moisture affects the tensile strength of the material. The laboratory is equipped with humidifiers which are regulated by an automatic control within approximately 1 per cent.

Skeins of 120 yards each were reeled off the bobbins of yarn made from the different grades of cotton and placed separately on racks constructed for this purpose. After a sufficient number of skeins had been reeled off to give positive results[1] they were allowed to condition in the testing room, having a temperature of 70° F. and a relative humidity of 65 per cent. Subsequently they were taken from the racks one at a time in rotation and broken with a power yarn tester, the downward stroke of the traverse moving at the rate of approximately 12 inches per minute.

Table III gives the result of the tensile-strength tests of 22's warp yarns made from five grades of eastern upland and five grades of western upland cotton.

TABLE III.—*Comparative tensile strength of 22's yarns in pounds per skein of 120 yards (mill tests).*

| Twist[1] constant. | Eastern upland. | | | | | | Western upland. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | M. F. | G. M. | M. | L. M. | G. O. | Av. | M. F. | G. M. | M. | L. M. | G. O. | Av. |
| 4.20 | 75.9 | 76.0 | 75.2 | 72.3 | 70.4 | 74.0 | 84.1 | 85.7 | 83.7 | 72.2 | 76.6 | 80.5 |
| 4.54 | 75.7 | 76.4 | 74.4 | 73.1 | 67.5 | 73.4 | 86.3 | 82.1 | 82.3 | 73.3 | 75.9 | 80.0 |
| 4.74 | 74.1 | 75.8 | 70.5 | 71.0 | 66.4 | 71.6 | 82.4 | 79.0 | 79.1 | 69.7 | 75.1 | 77.1 |
| 4.95 | 72.5 | 69.8 | 69.8 | 69.6 | 67.6 | 69.9 | 82.7 | 78.9 | 78.5 | 69.1 | 71.9 | 76.2 |
| Average | 74.6 | 74.5 | 72.5 | 71.5 | 68.0 | 72.2 | 83.9 | 81.4 | 80.9 | 71.1 | 74.9 | 78.5 |

[1] See footnote, p. 17.

Table III shows that the grade of the cotton does not always govern the tensile strength of the yarn.

During the month of June, 1915, within which this cotton was purchased, it was not possible to secure different grades of cotton from over equally distributed areas in each section or zone where it was produced. This was especially true in the sections west of the Mississippi River. The soil and weather conditions often vary considerably within the same zone, and even if several bales of cotton originated from the same locality it is entirely possible for conditions to affect the tensile strength of the yarn differently.

---

[1] By taking subtotals and averaging the tensile strength it was found that 24 skeins usually were sufficient.

The inconsistent variations shown by the tensile-strength test suggest to the manufacturer who wishes to maintain more uniform results in the manufactured product the importance of thorough mixing.

In practically every case the yarn made from western upland cotton was stronger than that made from the corresponding grades of eastern cotton, the difference being from 5 to 9 pounds per skein of 120 yards. This observation sustains the prevailing opinion that western upland cotton produces a stronger yarn than eastern, because its staple is of a heavier body. The fibers are greater in diameter and more wiry. For these reasons it is better suited for warp yarns than eastern upland cotton. The latter is better suited for filling and hosiery yarns because of its softness and pliability. However, in the waste cleaning processes western upland cotton lost more than eastern upland cotton.

Figure 4 shows graphically a comparison of the tensile strength in pounds per skein of 120 yards each of yarn made from eastern upland and western upland cotton. The 22's warp yarn with 22.23 turns per inch, or a twist constant[1] of 4.74, was used for this comparison.

Table III also shows the effect of the different twists per inch in the manufacture of 22's yarn made from the five grades of eastern and western upland cotton, respectively. There were used four twist constants, namely, 4.20, 4.54, 4.74, and 4.95, which represent, respectively, 19.7, 21.31, 22.23, and 23.22 turns of twist per inch.

Contrary to the general belief, the twist constant 4.74, the nearest obtainable to 4.75, which is considered as the warp yarn standard for upland cotton, did not produce the strongest yarn, showing that the points at which twist added strength to the yarn had been exceeded. (See also Table V, Textile school tests.) The turns per inch inserted in the yarn were verified by actual count after the yarn had been spun.

While the purpose of these tests was primarily to determine the relative percentages of waste in the different grades of cotton, the wide variation in the tensile strength served to show that the grade and staple of cotton does not always indicate accurately the strength of the yarn. Some other characteristics influencing the quality of the manufactured product, especially the tensile strength, can not be recognized by the present inexact method of judging the quality of raw cotton. Irregularities in the manufactured product are minimized by adequate methods of mixing the cotton for manufacturing.

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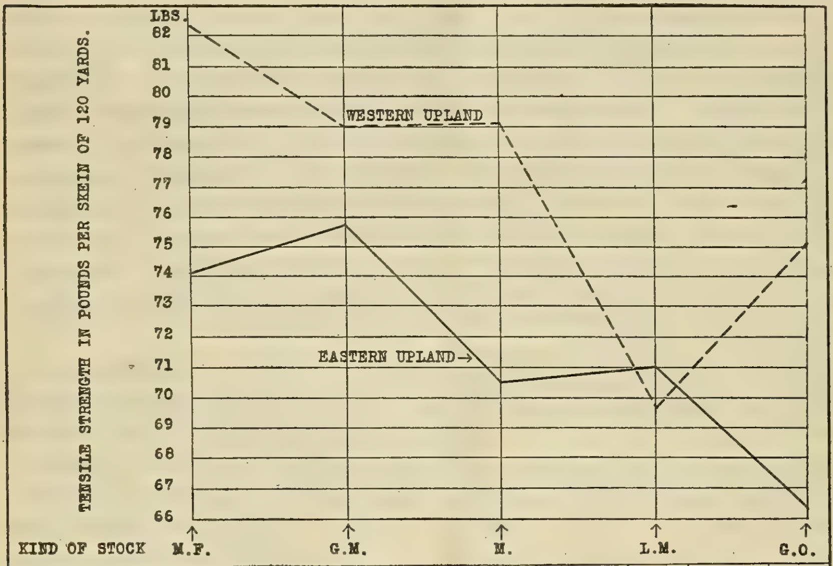
[1] Twist constant 4.75 is considered as standard for warp yarns, upland cotton. The twist per inch inserted in the yarn will be found by multiplying the square root of the number of yarns by the twist constant.

## SPINNING TESTS AT TEXTILE SCHOOL.

It was deemed advisable to make tests under different conditions; therefore, tests were made both in commercial mills and in textile schools.



| KIND OF STOCK | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| EASTERN UPLAND | 74.1 | 75.8 | 70.5 | 71.0 | 66.4 |
| WESTERN UPLAND | 82.4 | 79.0 | 79.1 | 69.7 | 75.1 |

FIG. 4.—The tensile strength of 22's warp yarn, made with 4.74 twist constant from the different grades of Eastern Upland and Western Upland cotton. (Mill tests.)

Fifty pounds from each of the 109 bales tested in the mill were sent to the textile department of the North Carolina State College of Agriculture and Engineering, West Raleigh, N. C. In conducting these tests the cotton originating from each of the different zones shown in figure 1 was tested separately. The mechanical conditions were made to duplicate as nearly as possible the conditions prevailing during the mill test. (See Table I.) In the textile-school tests the cotton passed through the following waste-cleaning machines: Opener and finisher, pickers, and cards.

TABLE IV.—*Waste percentages of the different grades of cotton from the different zones (textile-school tests).*

| Zones | Piedmont Plateau. | | | | | Atlantic Coastal Plains. | | | | | Eastern Gulf Coastal Plains. | | | | | Western Gulf Coastal Plains. | | | | | Western Prairie Lands and Plateau. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grades | M. F. | G. M. | M. | L. M. | G. O. | M. F. | G. M. | M. | L. M. | G. O. | M. F. | G. M. | M. | L. M. | G. O. | M. F. | G. M. | M. | L. M. | G. O. | M. F. | G. M. | M. | L. M. | G. O. |
| Net weight fed to pickers, pounds | 45.06 | 147.25 | 144.63 | 192.62 | 244.06 | 98.12 | 197.00 | 193.37 | 146.44 | 191.31 | 96.56 | 142.94 | 193.31 | 241.69 | 241.13 | 96.06 | 144.62 | 186.69 | 190.25 | 239.88 | 144.93 | 375.50 | 331.07 | 329.25 | 533.37 |
| *Machines and kinds of waste.* | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pickers: | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visible— | | | | | | | | | | | | | | | | | | | | | | | | | |
| Breaker, motes and fly | .26 | .38 | 1.00 | 1.10 | 1.95 | .57 | .70 | .97 | 1.28 | 2.09 | .38 | .70 | 1.06 | 1.40 | 2.39 | .52 | .60 | .94 | 1.12 | 2.20 | .48 | .52 | 1.19 | 1.44 | 2.32 |
| Finisher, motes and fly | .22 | .34 | .88 | .82 | 1.40 | .45 | .52 | .73 | 1.04 | 1.52 | .40 | .52 | .79 | 1.18 | 1.73 | .48 | .49 | .86 | 1.11 | 1.71 | .33 | .49 | .97 | 1.13 | 1.74 |
| Total visible | .48 | .72 | 1.88 | 1.92 | 3.35 | 1.02 | 1.22 | 1.70 | 2.32 | 3.61 | .78 | 1.22 | 1.85 | 2.58 | 4.12 | 1.00 | 1.09 | 1.80 | 2.23 | 3.91 | .81 | 1.01 | 2.16 | 2.57 | 4.06 |
| Invisible | [1].06 | .09 | .65 | 1.11 | 1.02 | [1]1.28 | .10 | .03 | [1].33 | .70 | [1].91 | [1].87 | .24 | .95 | .96 | [1].58 | [1].26 | [1].12 | [1].62 | 1.61 | .11 | [1].81 | .39 | [1].30 | .94 |
| Total visible and invisible | .42 | .81 | 2.53 | 3.03 | 4.37 | [1].26 | 1.32 | 1.73 | 1.99 | 4.31 | [1].13 | .35 | 2.09 | 3.53 | 5.08 | .42 | .83 | 1.68 | 1.61 | 5.52 | .92 | .20 | 2.55 | 2.27 | 5.00 |
| Cards:[2] | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visible— | | | | | | | | | | | | | | | | | | | | | | | | | |
| Flat strippings | 2.54 | 2.40 | 2.78 | 2.66 | 3.08 | 2.87 | 2.43 | 2.84 | 2.95 | 3.21 | 2.81 | 2.77 | 2.86 | 3.07 | 3.64 | 1.95 | 1.94 | 2.44 | 2.60 | 2.86 | 2.17 | 2.32 | 2.71 | 3.12 | 3.78 |
| Cylinder and doffer strippings | .65 | .56 | .88 | .96 | .95 | 1.01 | .77 | .97 | 1.00 | .92 | .82 | .71 | .69 | .92 | 1.04 | .74 | .58 | .74 | .77 | .91 | .50 | .72 | .92 | 1.05 | 1.39 |
| Motes and fly | 1.05 | 1.18 | 1.80 | 1.92 | 3.04 | 1.58 | 1.26 | 1.62 | 2.05 | 2.75 | .96 | 1.43 | 1.77 | 2.80 | 3.81 | 1.20 | 1.41 | 2.05 | 2.56 | 3.32 | 1.11 | 1.27 | 1.87 | 2.49 | 4.12 |
| Sweepings | .15 | .22 | .15 | .06 | .20 | .35 | .15 | .18 | .13 | .15 | .14 | .11 | .15 | .18 | .21 | .23 | .09 | .19 | .15 | .28 | .20 | .08 | .15 | .13 | .09 |
| Total visible | 4.39 | 4.36 | 5.61 | 5.60 | 7.27 | 5.81 | 4.61 | 5.61 | 6.13 | 7.03 | 4.73 | 5.02 | 5.47 | 6.97 | 8.70 | 4.12 | 4.02 | 5.42 | 6.08 | 7.37 | 3.98 | 4.39 | 5.65 | 6.79 | 9.38 |
| Invisible | [1].25 | .31 | 0.00 | .21 | [1].06 | [1]1.15 | .04 | 0.00 | [1].19 | .12 | [1].30 | [1].20 | .15 | .12 | .03 | [1].37 | [1].15 | [1].35 | [1].04 | .20 | [1]1.21 | [1].02 | [1].20 | .61 | [1].25 |
| Total visible and invisible | 4.14 | 4.67 | 5.61 | 5.81 | 7.21 | 4.66 | 4.65 | 5.61 | 5.94 | 7.15 | 4.43 | 4.82 | 5.62 | 7.09 | 8.73 | 3.75 | 3.87 | 5.07 | 6.04 | 7.57 | 2.77 | 4.37 | 5.45 | 7.40 | 9.13 |
| Pickers and cards:[3] | | | | | | | | | | | | | | | | | | | | | | | | | |
| Visible | 4.85 | 5.05 | 7.34 | 7.35 | 10.30 | 6.84 | 5.77 | 7.21 | 8.33 | 10.33 | 5.52 | 6.22 | 7.20 | 9.30 | 12.37 | 5.10 | 5.07 | 7.13 | 8.21 | 10.87 | 4.75 | 5.39 | 7.66 | 9.21 | 12.97 |
| Invisible | [1].31 | .40 | .65 | 1.31 | .96 | [1]2.43 | .14 | .03 | [1].52 | .82 | [1]1.21 | [1]1.07 | .39 | 1.07 | .99 | [1].95 | [1].41 | [1].46 | [1].66 | 1.80 | [1]1.09 | [1].83 | .20 | .30 | .70 |
| Total visible and invisible | 4.54 | 5.45 | 7.99 | 8.66 | 11.26 | 4.41 | 5.91 | 7.24 | 7.81 | 11.15 | 4.31 | 5.15 | 7.59 | 10.37 | 13.36 | 4.15 | 4.66 | 6.67 | 7.55 | 12.67 | 3.66 | 4.56 | 7.86 | 9.51 | 13.67 |
| Average loss for each zone | 7.58 | | | | | 7.30 | | | | | 8.16 | | | | | 7.14 | | | | | 7.85 | | | | |

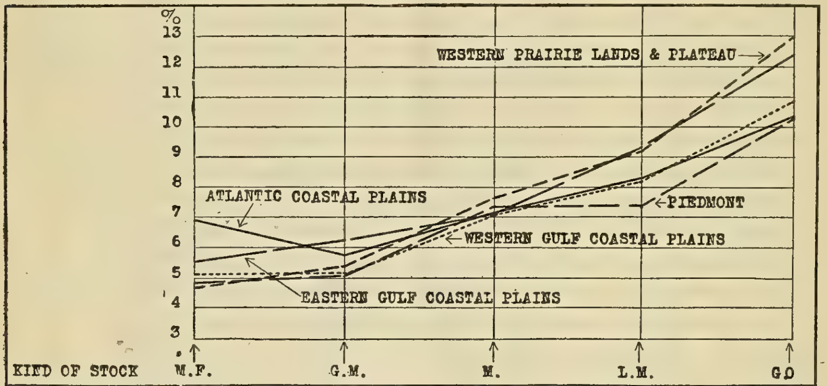
[1] Gain.

[2] Based on the net weight fed to the cards.

[3] Based on the net weight fed to the pickers.

### WASTE PERCENTAGES.

Table IV gives the results of the waste determinations as found in the textile-school tests. These figures were computed in the same manner as those in Table II. Net weights were used in making calculations, the tare not being included. Since approximately 50 pounds from each bale were used in the textile-school tests, the number of different bales of each grade represented is shown by the total weight given for each grade. The waste percentages of the five grades from the different zones are placed side by side in order to facilitate comparison.



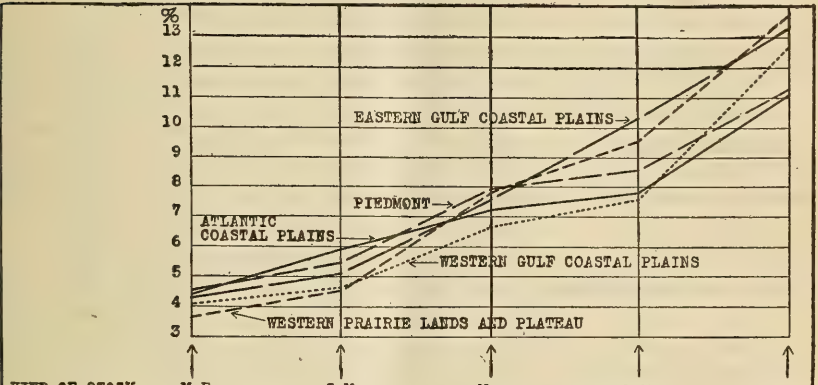
| KIND OF STOCK | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| PIEDMONT PLATEAU | 4.85 | 5.05 | 7.34 | 7.35 | 10.30 |
| ATLANTIC COASTAL PLAINS | 6.84 | 5.77 | 7.21 | 8.33 | 10.33 |
| EASTERN GULF COASTAL PLAINS | 5.52 | 6.22 | 7.20 | 9.30 | 12.37 |
| WESTERN GULF COASTAL PLAINS | 5.10 | 5.07 | 7.13 | 8.21 | 10.87 |
| WESTERN PRAIRIE LANDS & PLATEAU | 4.75 | 5.39 | 7.66 | 9.21 | 12.97 |

FIG. 5.—The visible waste percentages of five grades of cotton from the different zones. (Textile school tests.)

A close analysis of these percentages shows that the waste has a consistent relationship to the grade of the cotton. The percentages of invisible waste, however, are neither as uniform nor as consistent as are the percentages of visible waste. (See discussion of Moisture, page —.)

Figure 5 represents graphically the percentages of visible waste in the cotton originating from each of the five zones and of the five grades tested from each zone. Figure 6 likewise represents the percentages of visible and invisible waste combined. There is relatively little variation between the percentages of waste in cotton of the same grade from the different zones.

The average percentages of total waste from the five grades from the Piedmont Plateau, Atlantic Coastal Plains, eastern Gulf Coastal Plains, western Gulf Coastal Plains, and the western Prairie Lands and Plateau are as follows: 7.58, 7.30, 8.16, 7.14, and 7.85, respectively. These figures are not given, however, as a criterion nor with the inference that such close relationship would always prevail. As a matter of fact, material differences in the percentage of waste for the same grade often are found in neighboring sections of the country. A number of the large manufacturers early in the cotton season each year test carefully various lots from several different sections of the cotton belt to determine which cotton is best suited for their use.



| KIND OF STOCK | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| PIEDMONT PLATEAU | 4.54 | 5.45 | 7.99 | 8.66 | 11.26 |
| ATLANTIC COASTAL PLAINS | 4.41 | 5.91 | 7.24 | 7.81 | 11.15 |
| EASTERN GULF COASTAL PLAINS | 4.31 | 5.15 | 7.59 | 10.37 | 13.36 |
| WESTERN GULF COASTAL PLAINS | 4.15 | 4.66 | 6.67 | 7.55 | 12.67 |
| WESTERN PRAIRIE LANDS & PLATEAU | 3.66 | 4.56 | 7.86 | 9.51 | 13.67 |

FIG. 6.—The combined visible and invisible waste percentages of five grades of cotton from the different zones. (Textile school tests.)

## TENSILE-STRENGTH COMPARISONS.

(Textile-school tests.)

The tensile-strength tests of the yarn spun from the cotton originating in the various zones were made as described on page 6. Table V gives the results of these tests for the different zones and the same grades from each zone. No. 22's yarn was used in each case. Three different twist constants were used in order to determine the relative tensile strength of yarns made from upland cottons with different twists per inch.

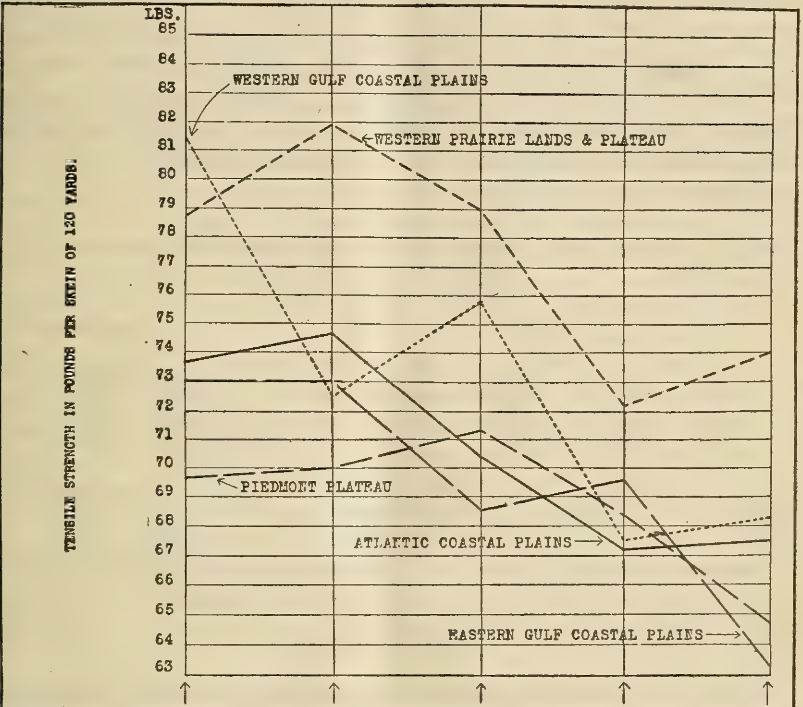
TABLE V.—*Tensile-strength comparisons of 22's yarn in pounds per skein of 120 yards each (textile-school tests).*

| Zone. | Twist constants. | M. F. | G. M. | M. | L. M. | G. O. | Average. |
|---|---|---|---|---|---|---|---|
| Piedmont Plateau | 4.29 | 70.8 | 71.9 | 73.4 | 70.0 | 64.0 | 70.0 |
| | 4.53 | 73.6 | 73.2 | 75.6 | 74.7 | 69.2 | 73.3 |
| | 4.76 | 69.7 | 70.0 | 71.3 | 68.3 | 64.7 | 68.8 |
| Average | | 71.4 | 71.7 | 73.4 | 71.0 | 66.0 | 70.7 |
| Atlantic Costal Plains | 4.29 | 74.1 | 75.1 | 70.5 | 68.4 | 68.2 | 71.3 |
| | 4.53 | 77.5 | 77.3 | 73.4 | 69.6 | 69.2 | 73.4 |
| | 4.76 | 73.7 | 74.7 | 70.4 | 67.2 | 67.5 | 70.7 |
| Average | | 75.1 | 75.7 | 71.4 | 68.4 | 68.3 | 71.8 |
| Eastern Gulf Coastal Plains | 4.29 | 72.4 | 70.3 | 68.1 | 68.5 | 63.5 | 68.6 |
| | 4.53 | 77.8 | 76.8 | 71.7 | 73.7 | 65.1 | 73.0 |
| | 4.76 | 73.0 | 73.0 | 68.6 | 69.6 | 63.4 | 69.5 |
| Average | | 74.4 | 73.4 | 69.5 | 70.6 | 64.0 | 70.4 |
| Average of eastern stock | | 73.6 | 73.6 | 71.4 | 70.0 | 66.1 | 71.0 |
| Western Gulf Coastal Plains | 4.29 | 88.3 | 74.7 | 77.6 | 66.8 | 69.9 | 75.5 |
| | 4.53 | 85.5 | 75.3 | 78.2 | 67.6 | 72.5 | 75.8 |
| | 4.76 | 81.4 | 72.6 | 75.8 | 67.5 | 68.2 | 73.1 |
| Average | | 85.1 | 74.2 | 77.2 | 67.3 | 70.2 | 74.8 |
| Western Prarie Lands and Plateau | 4.29 | 78.9 | 84.5 | 82.6 | 73.6 | 74.5 | 78.8 |
| | 4.53 | 82.5 | 87.9 | 84.0 | 78.0 | 79.6 | 82.4 |
| | 4.76 | 78.8 | 81.9 | 79.0 | 72.2 | 74.0 | 77.2 |
| Average | | 80.1 | 84.8 | 81.9 | 74.6 | 76.0 | 79.5 |
| Average of western stock | | 82.6 | 79.5 | 79.6 | 71.0 | 73.1 | 77.2 |

The variations in the tensile strength of yarn made from cotton originating in the Piedmont Plateau, Atlantic Coastal Plains, and eastern Gulf Coastal Plains conform closely to the grade of the cotton, but the tensile strength of yarn made from cotton originating in the western Gulf Coastal Plains or western Prairie Lands and Plateau does not bear the same relationship to the grade. The same relationship in the tensile strength of Low Middling and Good Ordinary is shown as in the tensile strength of yarn made from the same grades of western upland cotton in the mill tests. (See Table III and discussion on p. 6.) Cotton from crops of several seasons must be tested before a safe basis for comparison can be established.

It will be observed also that in the textile-school tests the twist constant 4.76, which was the nearest obtainable to 4.75, known as the twist standard for upland cotton of approximately 1-inch staple, did not produce yarn with a maximum tensile strength. The average tensile strength of the five grades in the different zones shows that the constant 4.53 produced stronger yarn than either 4.76 or 4.29. Constants 4.29, 4.53, and 4.76 represent, respectively, 20.12, 21.25, and 22.32 turns per inch for twist for 22's yarn. Practically the same results were found in the mill tests. (See Table III.) The twists per inch in the yarn were verified by untwisting the yarn and counting the turns per inch.

Figure 7 represents graphically the comparative tensile strength of 22's yarn, manufactured with 4.76 constant, made from the five different grades of cotton originating in the various zones (see fig. 1). The tensile strength is in pounds per skein of 120 yards with the downward stroke of the traverse moving at the rate of 12 inches per minute. The figures in the table in the lower part of the graph were taken from Table V and placed here for convenient reference.



| KIND OF STOCK | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| PIEDMONT PLATEAU | 69.7 | 70.0 | 71.3 | 68.3 | 64.7 |
| ATLANTIC COASTAL PLAINS | 73.7 | 74.7 | 70.4 | 67.2 | 67.5 |
| EASTERN GULF COASTAL PLAINS | 73.0 | 73.0 | 68.6 | 69.6 | 63.4 |
| WESTERN GULF COASTAL PLAINS | 81.4 | 72.6 | 75.6 | 67.5 | 68.2 |
| WESTERN PRAIRIE LANDS & PLATEAU | 78.8 | 81.9 | 79.0 | 72.2 | 74.0 |

FIG. 7.—The tensile strength of 22's yarn made with 4.76 twist constant from five grades of cotton from each of the several zones. (Textile school tests.)

## WEATHER, RELATIVE HUMIDITY, AND MOISTURE CONTENT DURING SPINNING TESTS.

(Mill and textile-school tests.)

The condition of the weather, relative humidity, and moisture content were taken into consideration during the entire time that the mill tests and the textile-school tests were in progress. The differences between the percentages of total waste as found in the mill tests and the total waste found in the textile-school tests (see Tables II and IV) are so great that, unless these conditions are considered, the results are confusing.

## WEATHER CONDITIONS.

Table VI gives the monthly averages of the maximum and of the minimum temperatures and the precipitation in Fall River, Mass., during the months of February, March, and April, and in Raleigh, N. C., during the months of May, June, and July, 1916, while the mill tests and the textile-school tests, respectively, were in progress. These averages were derived from reports of the Weather Bureau, which show the maximum and minimum temperatures and the precipitation for each day.

TABLE VI.—*Average daily maximum and minimum outside temperatures and the total precipitation during the tests.*

| Month. | Mill tests. | | | Month. | Textile-school tests. | | |
|---|---|---|---|---|---|---|---|
| | Average maximum temperature. | Average minimum temperature. | Total precipitation. | | Average maximum temperature. | Average minimum temperature. | Total precipitation. |
| | *Degrees.* | *Degrees.* | *Inches.* | | *Degrees.* | *Degrees.* | *Inches.* |
| February | 31.0 | 20.4 | 5.14 | May | 81.7 | 61.7 | 2.95 |
| March | 36.2 | 23.8 | 3.77 | June | 83.2 | 64.0 | 7.17 |
| April | 50.3 | 37.7 | 4.78 | July | 84.4 | 69.7 | 8.09 |
| Average | 39.2 | 27.3 | 4.56 | Average | 83.1 | 65.1 | 6.07 |

## RELATIVE HUMIDITY.

During the time the cotton was being manufactured humidifiers were regulated so as to maintain as nearly as possible a constant humidity, but in the picker rooms at the mill there were no humidifiers. In each room self-recording hygrometers were used, which made complete records night and day of moisture and temperature during the test while the various grades of cotton were in the course of manufacture. Table VII shows these results.

TABLE VII.—*Relative humidity and inside temperature during the tests.*

MILL TESTS.

| Kind of cotton. | Room. | M. F. | | G. M. | | M. | | L. M. | | G. O. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Average temperature. | Average relative humidity. | Average temperautre. | Average relative humidity. | Average temperature. | Average relative humidity. | Average temperature. | Average relative humidity. | Average temperature. | Average relative humidity. |
| Eastern upland | Picker: | | | | | | | | | | |
| | Opener | 78.5 | 46.9 | 66.5 | 56.9 | 71.2 | 59.2 | 78.9 | 49.5 | 74.9 | 52.9 |
| | Breaker | 78.3 | 38.6 | 73.0 | 48.3 | 72.6 | 38.4 | 74.5 | 42.3 | 72.7 | 47.6 |
| | Finisher | 77.4 | 42.5 | 73.1 | 51.1 | 73.3 | 35.9 | 73.8 | 43.0 | 72.8 | 47.2 |
| | Card | 70.6 | 48.9 | 71.8 | 52.1 | 69.7 | 50.4 | 72.6 | 50.9 | 71.2 | 51.3 |
| | Spinning | 81.8 | 54.1 | 81.8 | 54.1 | 81.8 | 54.1 | 81.8 | 54.1 | 81.8 | 54.1 |
| Western upland | Picker: | | | | | | | | | | |
| | Opener | 69.5 | 47.9 | 76.7 | 46.3 | 69.2 | 38.9 | 73.0 | 46.0 | 71.4 | 48.5 |
| | Breaker | 69.0 | 41.2 | 65.5 | 41.3 | 67.2 | 44.7 | 67.5 | 45.5 | 64.2 | 45.3 |
| | Finisher | 69.6 | 43.9 | 67.4 | 46.9 | 67.5 | 45.8 | 67.6 | 44.8 | 63.1 | 49.9 |
| | Card | 71.6 | 52.6 | 71.0 | 48.7 | 70.4 | 50.0 | 69.6 | 48.3 | 68.9 | 46.9 |
| | Spinning | 81.8 | 54.1 | 81.8 | 54.1 | 81.8 | 54.1 | 81.8 | 54.1 | 81.8 | 54.1 |
| TEXTILE-SCHOOL TESTS. | | | | | | | | | | | |
| Piedmont Plateau | Picker: | | | | | | | | | | |
| | Opener | 82.0 | 68.4 | 82.2 | 63.7 | 80.4 | 62.7 | 81.0 | 55.5 | 80.3 | 56.2 |
| | Finisher | 83.0 | 69.0 | 83.8 | 63.0 | 81.5 | 58.0 | 82.8 | 58.9 | 81.0 | 64.5 |
| | Card[1] | 84.6 | 65.4 | 78.1 | 60.0 | 78.7 | 53.8 | 78.8 | 56.0 | 79.6 | 59.3 |
| Atlantic Coastal Plains | Picker: | | | | | | | | | | |
| | Opener | 76.8 | 63.6 | 78.0 | 58.2 | 82.0 | 60.4 | 80.4 | 60.6 | 82.0 | 61.0 |
| | Finisher | 78.0 | 61.3 | 78.0 | 64.5 | 84.0 | 57.9 | 80.8 | 59.8 | 82.0 | 61.6 |
| | Card[1] | 78.9 | 57.8 | 79.2 | 58.8 | 80.3 | 53.5 | 79.6 | 60.1 | 81.4 | 58.5 |
| Eastern Gulf Coastal Plains | Picker: | | | | | | | | | | |
| | Opener | 80.0 | 66.4 | 80.6 | 65.9 | 85.0 | 57.6 | 89.3 | 57.9 | 83.3 | 55.8 |
| | Finisher | 80.0 | 63.5 | 81.8 | 66.6 | 85.3 | 60.9 | 90.0 | 58.0 | 83.0 | 60.3 |
| | Card[1] | 81.6 | 59.4 | 83.8 | 59.4 | 82.8 | 59.4 | 84.3 | 57.8 | 81.3 | 61.3 |
| Western Gulf Coastal Plains | Picker: | | | | | | | | | | |
| | Opener | 89.3 | 58.1 | 92.0 | 52.7 | 92.0 | 58.5 | 83.6 | 64.1 | 84.1 | 53.9 |
| | Finisher | 90.0 | 57.8 | 91.8 | 54.9 | 92.0 | 60.2 | 83.6 | 63.7 | 85.9 | 53.2 |
| | Card[1] | 86.1 | 60.4 | 86.8 | 60.0 | 84.3 | 63.3 | 83.5 | 60.8 | 81.3 | 57.3 |
| Western Prairie Lands and Plateau | Picker: | | | | | | | | | | |
| | Opener | 87.5 | 56.9 | 82.4 | 63.5 | 88.4 | 60.8 | 81.9 | 68.8 | 88.1 | 54.9 |
| | Finisher | 88.0 | 55.7 | 84.4 | 63.3 | 90.0 | 60.3 | 85.1 | 65.7 | 88.0 | 54.5 |
| | Card[1] | 82.7 | 62.7 | 85.4 | 66.4 | 82.2 | 69.0 | 86.5 | 61.0 | 83.8 | 72.8 |

[1] Card and spinning machinery in one large room.

### MOISTURE DETERMINATIONS.

At both the mill and the textile school, samples of the cotton were selected for moisture tests from each place in the processes of manufacture where the stock was weighed. These samples were placed in air-tight cans, weighed carefully on equal arm balances sensitive to 0.05 grams, shipped to Washington, reweighed in the same manner, and then tested in the cotton-testing laboratory for moisture content. Table VIII gives the results of these tests.

TABLE VIII.—*Percentages of moisture in cotton of the different grades at various points in the cotton-manufacturing processes.*

MILL TESTS.

| Kind of cotton. | Stage. | | | |
|---|---|---|---|---|
| | Warehouse.[1] | Opener picker. | Finisher picker. | Cards. |
| Eastern upland: | | | | |
| Middling fair | 8.65 | 9.03 | 7.13 | 5.83 |
| Good middling | 9.27 | 8.73 | 7.36 | 6.01 |
| Middling | 9.11 | 9.03 | 6.26 | 5.47 |
| Low middling | 9.17 | 8.83 | 5.83 | 5.03 |
| Good ordinary | 9.48 | 9.12 | 6.20 | 5.18 |
| Western upland: | | | | |
| Middling fair | 9.30 | 8.47 | 6.68 | 5.60 |
| Good middling | 9.38 | 8.54 | 5.96 | 5.12 |
| Middling | 9.02 | 8.31 | 6.17 | 5.21 |
| Low middling | 8.96 | 8.57 | 6.31 | 5.41 |
| Good ordinary | 9.36 | 8.95 | 6.37 | 5.12 |
| TEXTILE-SCHOOL TESTS. | | | | |
| Piedmont Plateau: | | | | |
| Middling fair | 6.50 | ............ | 7.56 | 7.07 |
| Good middling | 6.05 | ............ | 7.02 | 6.50 |
| Middling | 6.37 | ............ | 6.49 | 5.56 |
| Low middling | 6.05 | 6.50 | ............ | 6.39 |
| Good ordinary | 6.36 | 6.00 | ............ | 6.27 |
| Atlantic Coastal Plains: | | | | |
| Middling fair | 5.78 | 6.62 | 6.45 | 5.66 |
| Good middling | 6.57 | 6.04 | 5.92 | 6.53 |
| Middling | 6.74 | 6.52 | 6.44 | 6.12 |
| Low middling | 5.92 | 6.30 | 6.54 | 6.34 |
| Good ordinary | 6.22 | 6.33 | 6.65 | 6.59 |
| Eastern Gulf Coastal Plains: | | | | |
| Middling fair | 6.32 | 6.16 | 6.70 | 7.15 |
| Good middling | 6.22 | 6.59 | 6.62 | 7.02 |
| Middling | 6.33 | 6.40 | 5.70 | 5.78 |
| Low middling | 7.31 | 7.89 | 6.07 | 5.87 |
| Good ordinary | 6.74 | 6.70 | 5.93 | 5.59 |
| Western Gulf Coastal Plains: | | | | |
| Middling Fair | 6.87 | 6.44 | 6.10 | 5.81 |
| Good Middling | 6.04 | 6.10 | 5.22 | 6.16 |
| Middling | 6.38 | 6.54 | 6.10 | 6.22 |
| Low Middling | 6.22 | ............ | ............ | 6.26 |
| Good Ordinary | 6.41 | 6.66 | 5.99 | 5.64 |
| Western Prairie Lands and Plateau: | | | | |
| Middling Fair | 6.83 | 6.02 | 5.73 | 6.67 |
| Good Middling | 7.02 | 6.64 | 6.58 | 6.64 |
| Middling | 6.59 | 6.70 | 6.69 | 6.78 |
| Low Middling | 6.12 | 7.05 | ............ | ............ |
| Good Ordinary | 7.16 | ............ | ............ | ............ |

[1] As there was no warehouse at the textile school, the cotton was stored in the textile building.

In each case the cotton was stored for several months prior to the time the tests were begun—at Fall River in a cotton warehouse, which was not heated; at West Raleigh in the textile-school building, which was heated until warm weather. The weather at Fall River was cold and damp, with considerable snow on the ground at the time the warehouse weights were obtained. The textile-school tests were in progress at West Raleigh during the summer, the temperature was high, and, as the cotton proceeded through the manufacturing processes, practically no loss of moisture was evident.

Table IX shows in brief the average temperature, relative humidity, and the percentage of moisture in the cotton while in the warehouse, picker room, and card room, both at the mill and at the textile school.

TABLE IX.—*The average temperature, relative humidity, and percentage of moisture in the cotton during the mill and textile-school tests.*

| Determination. | Mill test. | | | Textile-school test. | | |
|---|---|---|---|---|---|---|
| | Warehouse. | Pickers. | Cards. | Warehouse. | Pickers. | Cards. |
| Average degree of temperature | 36.8 | 70.6 | 70.8 | 80 | 84.6 | 82.2 |
| Average relative humidity | 72.8 | 45.1 | 50.0 | 53 | 60.7 | 60.3 |
| Average percentage of moisture | 9.17 | 6.44 | 5.40 | 6.47 | 6.33 | 6.28 |

The average moisture in the cotton when the tests were begun at Fall River was 9.17 per cent, as determined by samples taken at the time the cotton was weighed in the warehouse. The average moisture in this same cotton taken during the time it was passing through the cards was 5.40 per cent, a loss of moisture alone of 3.77 per cent of the weight of the cotton. The average moisture in the cotton when the tests were begun at West Raleigh, N. C., was 6.44 per cent, as determined by samples taken at the time it was weighed in the warehouse. The average moisture in this same cotton while it was passing through the cards was 6.28 per cent, a loss of moisture of only 0.16 per cent of the weight of the cotton.

Referring to Tables II and IV, it will be observed that the invisible waste at the mill ranged from a 3 per cent to a 5 per cent loss, while at the textile school there was sometimes a slight gain and sometimes a slight invisible loss. If the waste percentages were corrected for moisture content, the results would be practically the same in each case. These findings also emphasize the need of an exact knowledge of the moisture content of cotton in the various stages of handling and marketing, and of maintaining proper atmospheric conditions while it is in the course of manufacture.

## MANUFACTURING PROPERTIES.

In determining the comparative manufacturing properties of the different grades of cotton it was found that better comparisons could be made by manufacturing the cotton representing all of the different grades into the same number of yarn. This method, while not conforming altogether to the general practices of the trade, simplified the comparisons and eliminated a number of factors which otherwise would have involved changes in the speeds, settings, and twist per inch in the yarn. Even with the method adopted, it was difficult to obtain specific data regarding all the factors involved in the spinning qualities of the different grades. As the grades decreased in quality from Middling Fair to Good Ordinary, the amount of dirt, dust, leaf, and short fibers afloat in the air increased progressively. For instance, when stripping the cards in the mill while the Good Ordinary cotton was being run through them it was necessary to open the windows because of the density of the dust. The use of low grade cotton is more disagreeable to the operatives; consequently it adds difficulty to the labor and mechanical problems.

A record was taken of the spinning qualities of the different grades by keeping an accurate count of the number of threads which broke. All such breakages, unless due to some mechanical defect, were charged against each grade. The following percentages of breakages on the spinning frame were found: Middling Fair, 12.1 per cent, Good Middling 13.8 per cent, Middling 14.4 per cent, Low Middling 27.5 per cent, and Good Ordinary 32.2 per cent.

These tests show that 100 pounds of raw cotton, net weight, of each of the different grades will produce the following pounds of yarn, not including the small loss which occurs in those processes subsequent to the cards: Middling Fair 91.57, Good Middling 90.95, Middling 88.93, Low Middling 87.2, and Good Ordinary 83.73 pounds. In considering the grade relations it should be remembered that there is a difference in the value of the yarns made from the various grades.

It was found by submitting a full line of samples to a number of the leading waste dealers and securing estimates of value for each sample that the value of the waste from a bale of cotton representing one grade is practically the same as the value of the waste from a bale of cotton representing any other grade, in that the price and quantity vary inversely. Any increase or decrease in the waste percentage causes a corresponding increase or decrease in the cost per pound of the manufactured product. A wasty cotton also produces an inferior product.

## BLEACHING TESTS OF YARN.

Portions of the yarns that were made from Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary of both eastern upland and western upland cotton in the mill tests, as well as cloth made from various combinations of these yarns, were tested for the bleaching properties. The tests were conducted on a commercial scale in a bleachery, and the results were checked subsequently in the New Bedford Textile School. The methods followed were those that are in common use.

### TESTS AT BLEACHERY.

*Scouring.*—The skeins of yarns were placed in a cloth bag near the center of a circulating kier, loaded with other goods, and were treated for 12 hours at 13 pounds pressure with a 2-degree Twaddell solution of sodium hydroxide containing 10.75 grams NaOH per liter. The samples were then washed with water five times while in the kier, which eliminated practically all alkali from the material. The goods were kept wet for some time before a bleaching vat was available, after which they were hydro-extracted and treated in a circulating vat.[1]

*Bleaching.*—The goods were placed in the center of a 300-pound load of commercial yarns, the ratio of liquor to the goods being in weight 10 to 1, and treated for 1½ hours with a 2.5-degree Twaddell solution of bleaching powder containing 1.26[2] grams of chlorine per liter. The goods were treated with a 1-degree Twaddell solution of sulphuric acid containing 6.80[2] grams per liter and then washed for 30 minutes. Finally, the goods were soaped 30 minutes in a solution containing 2 per cent[3] of 88 per cent soap chips. The skeins were blued by treating them 20 minutes in a water solution containing 0.055 per cent of methylene blue. After the skeins were hydro-extracted they were dried for 3½ hours on a truck drier heated to a temperature of 120° F.

*Qualities of bleach.*—The grades in the order of whiteness obtained by bleaching are as follows, beginning with the best:

Good Middling, western.
Good Middling, eastern.
Middling Fair, western.
Middling Fair, eastern.
Middling, western.
Middling, eastern.
Low Middling, western.
Low Middling, eastern.
Good Ordinary, western.
Good Ordinary, eastern.

Cotton yarn made from Low Middling western upland and Low Middling eastern upland cotton produced goods having a somewhat slaty hue. Yarns made from the Good Ordinary, both eastern upland and western upland cotton, did not bleach satisfactorily in that a decided bluish cast was apparent.

### TEXTILE-SCHOOL TESTS.

Subsequent tests were made in the New Bedford Textile School in order to check the determinations made in the commercial bleachery. They included tests of the whiteness, tensile strength, weight losses, and moisture content at each operation.

*Scouring.*—The scouring[4] was done with 10 per cent soda ash and 5 per cent soap. The goods were boiled five hours, rinsed well with hot water at 75° C. and then in cold water at 23° C., after which they were acidulated with 1 per cent solution of sulphuric acid, rinsed freely in water until free from acid, and dried.

*Bleaching.*—Samples of the wet yarn were taken after the last rinsing and bleached at 23.3° C. in a solution of bleaching powder containing 2 grams per liter of chlorine. The goods were left in this solution for 43 minutes, after which they were rinsed freely in cold water, soured in a 1 per cent solution of acetic acid, and rinsed again. As there was still a slight trace of chlorine, the goods were treated in a 2.5° Twaddell solution of hyposulphite of soda at 22° C. for 30 minutes. They were then rinsed freely in cold water and dried.

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[1] This vat was constructed in such a way that the skeins were supported by rods in a comparatively loose condition, and the liquor was circulated through them by mechanical means.

[2] The liquor was kept overnight in a well-corked bottle and the analysis was made on the following morning.

[3] The percentages given in the bleaching tests are calculated on the weight of goods treated unless otherwise stated.

[4] The volume of liquor used in the textile-school tests was fifteen times the weight of the goods treated.

This method does not take into consideration the actual time that would be required to bleach the different yarns made from the different grades of cotton. The yarns were all treated under identical conditions, and at the same time. The lower grades could have been bleached more satisfactorily if the factors of time, strength of bleach liquor, and temperature had been altered. The treatment of all the material in the same way, however, gave a satisfactory basis for comparison.

These tests substantiated the following conclusions reached in the tests made in the commercial bleachery: The yarns made from Middling Fair and Good Middling were practically identical in color after bleaching; the yarns made from Middling were not quite as glossy or "bloomy" in their appearance, but for commercial purposes produced satisfactory results; the yarns made from Low Middling gave a slightly slaty color when compared closely with the higher grades; and the yarns made from Good Ordinary did not bleach satisfactorily, i. e., under the same conditions, in that they had a decided slaty bluish cast when compared closely with the yarns from the Middling cotton or that of better grades.

While these tests were in progress, moisture determinations were made from time to time. Bleaching, calculated on a dry basis, caused an average loss in weight for the eastern cotton of 4.69 per cent in the textile school test and 5.14 per cent in the commercial test.

The average loss in weight due to bleaching of the western cotton was 4.78 per cent in the textile-school test and 5.24 per cent in the mill test. This difference probably was caused by the 12-hours caustic-soda boil under pressure in the mill tests. Several different concentrations of bleaching liquor were used in the textile-school test; namely, 1, 2, 3, and 4 grams per liter of chlorine. There was practically no difference in weight losses due to bleaching.

The loss in tensile strength due to the bleaching processes was 12.25 per cent in the eastern cotton, and 16.40 per cent in the western cotton. These results were influenced somewhat by a slight difference in the moisture content, but this difference was such that it would serve further to increase the loss in the western cotton. The results seem to indicate that in the bleaching processes chemicals act more readily on upland cotton grown west of the Mississippi River than on corresponding grades of eastern upland cotton, because under the same conditions the strength of the yarn made from the western upland cotton was affected more readily and a better bleach was obtained.

## BLEACHING TESTS OF PIECE GOODS.

### MILL TESTS.

Warp and filling yarns made from each of the five grades of upland cotton produced east and west of the Mississippi River, were woven into cloths composed of different combinations of warp and filling. These were marked carefully for identification, and bleached in a commercial bleachery. Exact duplicates were retained "in the gray" for comparative purposes. The goods were given a plain "sheeting finish," that is, they were scoured twice in a closed kier, bleached, starched, dried, and calendered.

*Scouring.*—In the first boiling process the cloth was placed in a horizontal wagon kier, near the center of a 6,500-pound lot of similar cloth. The steam turned on, and a good circulation of the liquor was established by a steam injector for 45 minutes. A 2-degree Twaddell solution of sodium hydroxide containing 8.9 grams per liter was used. The circulation was continued at 6 to 7 pounds pressure for 10 hours. The goods were cooled in the kier before the latter was opened by flushing with water.

*Washing and scouring.*—The goods were washed [1] through cold water, acidulated [2] in a scouring machine, with a 1-degree Twaddell solution of sulphuric acid, containing 11.42 grams per liter, piled on a wooden rack 30 minutes, to allow the acid to act, again washed, and run into a vertical kier.

*Second boiling process.*—The goods were placed about one-third of the way down from the top of a vertical kier, containing 10,000 pounds of cloth which was being treated for commercial purposes. The liquor used in this kier was a 1-degree Twaddell solution of caustic soda containing 5 grams per liter. Good circulation and proper temperature were established within 1¼ hours, and then the material was boiled for 9 hours at 6 to 7 pounds pressure, after which the kier was flushed twice with cold water and the goods run into a log washing machine.

*Washing and bleaching.*—The goods were washed twice with a plentiful supply of clean water, and the cloth was piled for examination. The material was then run through a ¾-degree Twaddell bleaching-powder solution[1] containing 2.3 grains of available chlorine per liter. It was allowed to stand in a pile until a good white was obtained, the time required being 1 hour and 5 minutes. The goods were then washed twice with clean water, and squeezed in a 4-roll water mangle at a speed of 124 yards per minute, with the lever set for a light pressure of approximately 500 pounds.

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[1] All the washing in the piece goods tests was done in a standard type "log" washer having a top press roll of wood about 18 inches in diameter and pit allowing a depth of 2 feet of water. The speed of these machines was from 80 to 90 yards per minute.

[2] The acidulating was done in a regular scouring machine consisting of a pit containing acid and a heavy set of squeeze rolls, with compound lever set at approximately 500 pounds pressure. This machine was provided with an automatic folding device by means of which about 800 yards were kept continuously immersed in the acid.

*Starching.*—The goods were passed at a speed of 120 yards per minute through a starch mangle, which contained the following mixture: 45 pounds of cornstarch; 10 ounces of bluing,[2] 20 ounces of tint.[3]

These ingredients were mixed with 100 gallons of water heated to a temperature of 180° F., and cooked to a paste, a subsequent analysis of which showed 3.015 per cent of solids.

*Drying and calendering.*—The goods were dried on a set of copper cylinders, after which they were allowed to cool, moistened on a rotary brush type sprinkler and calendered cold at a speed at 104 yards per minute on a three-roll calender. A rigid bow expander was used to obtain the width. Finally, the goods were measured off on a yarding machine, inspected, and packed.

By selecting the 10 gray pieces of cloth woven in both the warp and filling from each of the five different grades of eastern upland cotton and the five different grades of western upland cotton, it was comparatively easy to arrange these samples in the order of the grades of cotton from which they were produced. The samples of the bleached cloth, however, produced from the Good Middling and Middling Fair cotton were indistinguishable as to the degree of whiteness; the bleached cloth representing the Middling cotton could be distinguished from the Good Middling and Middling Fair by very close comparison; the cloth made from Low Middling bleached comparatively well, but with a less degree of lustre and brightness; while the cloth produced from the grade of Good Ordinary cotton could be distinguished readily by the bluish cast.

Each of these 10 samples of bleached cloth was presented to a number of cloth brokers, and it was the general opinion that the cloth representing the grades of Middling Fair, Good Middling, and Middling were of the same money value, but that preference would be given in the markets to cloth produced from the higher grades. The bleached cloth made from Low Middling and Good Ordinary would not be accepted as of equal value with that produced from the higher grades.

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[1] The bleaching machine was similar to the scouring machine, but ran at a speed of from 100 to 110 yards per minute. From 100 to 500 yards of cloth were kept in the bleaching solution.

[2] A solution of blue basic dye.

[3] A solution of a reddish-blue basic dye.

### COMPARISON OF THE RESULTS OF SPINNING TESTS OF THE OLD PERMISSIVE COTTON GRADES WITH THE PRESENT OFFICIAL COTTON STANDARDS.

The spinning tests of the old permissive grades[1] were conducted in a representative mill at Danville, Va., in the fall of 1913 on cotton from the 1912 crop. The spinning tests on the present Official Cotton Standards were conducted at Fall River, Mass., in the spring of 1916 on cotton from the 1914 crop. In each case approximately 110 bales were used, representing Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary. The old permissive grades were established by the Secretary of Agriculture in February, 1909, and copies were distributed and used until they were superseded by the present Official Cotton Standards of the United States, established and promulgated December 14, 1914, and reestablished and repromulgated August 11, 1916.

Table X gives the visible, invisible, and total waste percentages and the tensile strength of the yarn of the different grades for each test. The waste percentages in each case represent the average of the results obtained from both the eastern and western cottons.

TABLE X.—*The average visible, invisible, and total waste percentages and the tensile strength of 22's warp yarn of the old permissive cotton grades compared with the present Official Cotton Standards (mill tests).*

| Determination. | Old permissive cotton grades, 1912 crop. | | | | | Present Official Cotton Standards, 1914 crop. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | M. F. | G. M. | M. | L. M. | G. O. | M. F. | G. M. | M. | L. M. | G. O. |
| Total visible waste through cards [1] | 5.12 | 5.97 | 6.88 | 9.53 | 11.32 | 4.61 | 5.32 | 6.85 | 8.12 | 10.67 |
| Total invisible waste through cards [1] | 2.67 | 2.75 | 3.66 | 4.21 | 4.42 | 3.82 | 3.73 | 4.22 | 4.68 | 5.60 |
| Total waste | 7.79 | 8.72 | 10.54 | 13.74 | 15.74 | 8.43 | 9.05 | 11.07 | 12.80 | 16.27 |
| Breaking strength, 22's warp yarn, in pounds per 120 yards. | 74.5 | 71.4 | 67.7 | 65.4 | 60.6 | 78.3 | 77.4 | 74.8 | 70.4 | 70.8 |

[1] Based on net weights fed to opener picker.

It will be observed that somewhat less visible waste was discarded from the different grades in the tests on the present Official Cotton Standards than on the old permissive grades; the invisible waste was greater and more nearly uniform for the various grades of the present Official Cotton Standards, while the total waste percentages, as shown by figure 8, were very similar.

The moisture content of the cotton representing the Official Cotton Standards when weighed at the warehouse just prior to the beginning of the tests and when weighed at the cards was 9.17 and 5.40 per cent, respectively, while the moisture content of the old permissive cotton grades at the same places was 7.95 and 6.06 per cent, respectively. These differences explain in part the differences described as invisible waste percentages.

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[1] These spinning tests were planned by Dr. N. A. Cobb, agricultural technologist, of the Bureau of Plant Industry, and were conducted by Messrs. D. E. Earle and W. S. Dean.

The spinning tests of the Official Cotton Standards showed that the western cotton was approximately 1 per cent more wasty than the eastern cotton, while with the old permissive grades the reverse was shown. In both tests the yarn (22's) made from the western cotton was approximately 3 pounds per skein stronger than that made from the eastern cotton.

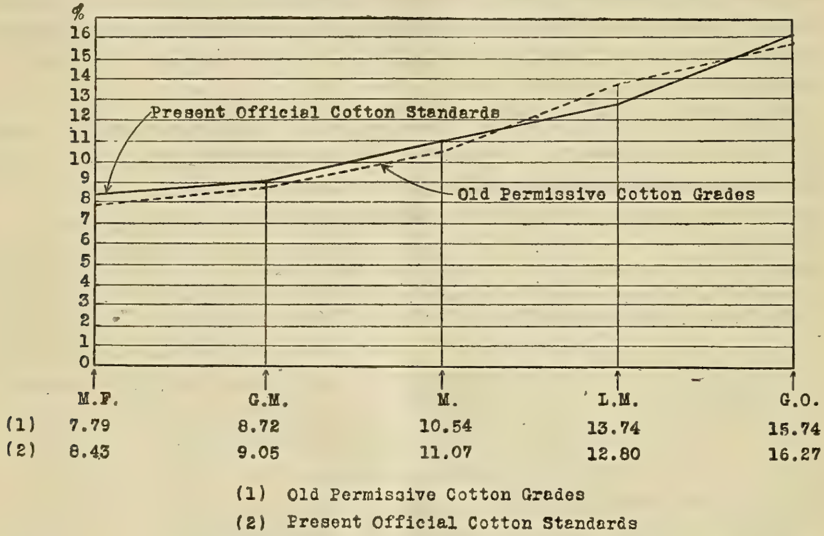
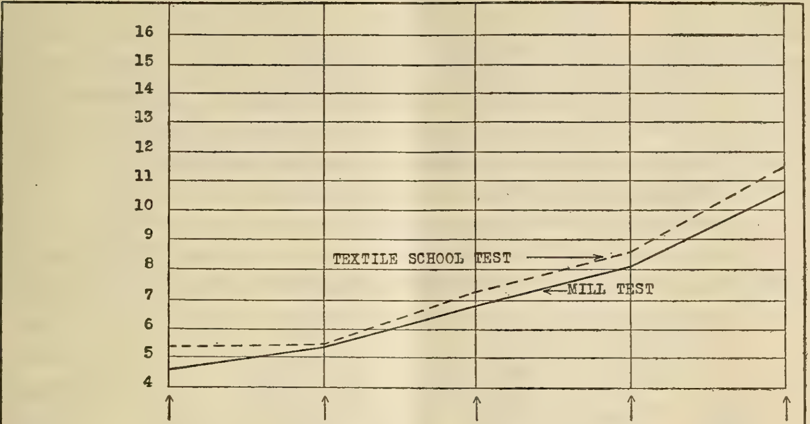


FIG. 8.—Total waste percentages of the old permissive cotton grades compared with those in the present Official Cotton Standards. (Mill tests.)

In this comparison a very close relation is shown to exist, especially with reference to the percentage of waste in each corresponding grade. While the tests were made on different crops under somewhat different conditions, a comparison of the results obtained in the two tests indicates that the changes which were made in the new grades made practically no difference in the waste percentages, but involved principally a change in the degree or depth of color, particularly in the lower grades.

## SUMMARY.

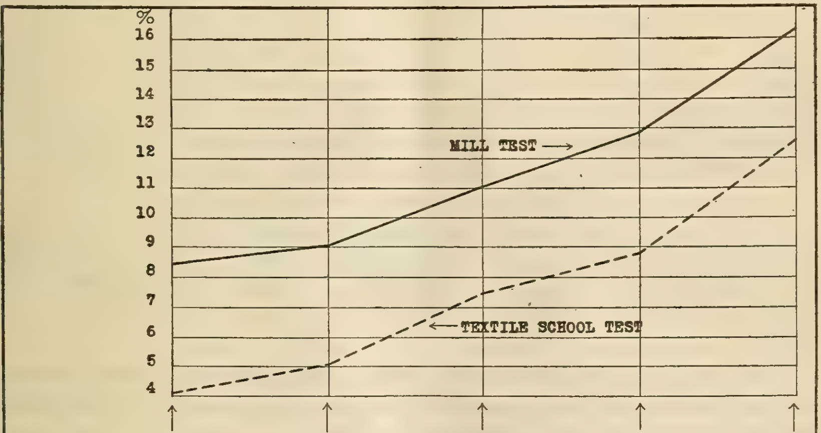
This bulletin gives the results of manufacturing tests made of cotton representing Middling Fair, Good Middling, Middling, Low Middling, and Good Ordinary of the Official Cotton Standards of the United States. The spinning and weaving tests were conducted in a cotton mill in the North, and check tests were made in a textile school, in the South, with a portion of the same bales of cotton. At each place, the different grades were tested under as nearly identical conditions as was possible.



| TEST | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| MILL | 4.61 | 5.32 | 6.85 | 8.12 | 10.67 |
| TEXTILE SCHOOL | 5.34 | 5.46 | 7.33 | 8.52 | 11.46 |

FIG. 9.—The visible waste percentages as found in mill and textile school tests.

The results of the spinning tests are summarized graphically in figures 9, 10, and 11. Figure 9 represents the average visible waste discarded in the manufacturing processes in both the textile school and mill tests for each of the five grades tested, while figure 10 represents the total waste percentages. The differences in the storage

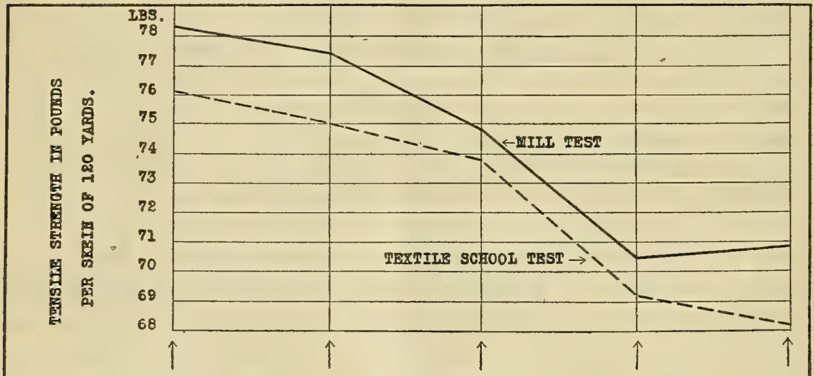


| TEST | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| MILL | 8.43 | 9.05 | 11.07 | 12.80 | 16.27 |
| TEXTILE SCHOOL | 4.17 | 5.06 | 7.44 | 8.74 | 12.55 |

FIG. 10.—The combined visible and invisible waste percentages, as found in the mill and textile school tests.

conditions as well as in the weather and location of the mill and textile school explain the differences in the waste percentages shown in figure 10, which represent largely the differences in the moisture content of the cotton. If the waste percentages were corrected for moisture content, the results at the mill and textile school would be practically the same. The results of the moisture determinations emphasize the need of a more exact knowledge of the moisture content of cotton in the various stages of handling and marketing it and of maintaining proper artificial atmospheric conditions while it is in the course of manufacture.

Tensile-strength tests were made of yarn which had been spun with the use of several twist constants. It was found that the constant of 4.75 which is generally considered standard for upland cottons was excessive. Figure 11 represents graphically the average tensile strength of 22's yarn in pounds per skein of 120 yards produced in the mill and the textile school for each of the five grades tested.



| TEST | M.F. | G.M. | M. | L.M. | G.O. |
|---|---|---|---|---|---|
| MILL | 78.3 | 77.4 | 74.8 | 70.4 | 70.8 |
| TEXTILE SCHOOL | 76.1 | 75.0 | 73.8 | 69.2 | 68.2 |

FIG. 11.—The average tensile strength of 22's yarn in pounds per skein of 120 yards each, as found in the mill and textile school tests. (4.75 twist constant used.)

The bleaching tests were conducted in bleacheries in Massachusetts, and the results checked in a textile school in the North. The results showed that when the goods made from each grade were bleached under identical conditions Middling Fair and Good Middling were practically identical in color. The goods made from Middling did not produce quite as pure a white as Middling Fair and Good Middling, but for commercial purposes gave satisfactory results; the goods made from Low Middling gave a slightly slaty color when closely compared with the other grades, while the goods made from Good Ordinary were easily distinguished by a slaty, bluish cast when compared with the goods made from Middling cotton or that of a better grade. The lower grades might have been bleached more satisfactorily if in some of the processes the factors of time, concentration, and temperature had been altered.

A comparison of the waste and tensile strength of the old permissive cotton grades, as determined by tests made in the fall of 1913 on the 1912 crop, with the results of tests made on the present Official Cotton Standards in the spring of 1916 on the 1914 crop, shows that the changes made in the revision of the old permissive grades did not change the percentages of waste in the corresponding grades, but involved principally the factor of color and affected chiefly the lower grades.

The tests based on the Official Cotton Standards of the United States show that after making allowances for the losses due to the cleaning processes there is comparatively little difference between the grades above and those below Middling in the price paid by the manufacturer for each pound of the usable cotton obtained from bales of the different grades, but that there is a difference in the intrinsic value per pound of the manufactured product. Accordingly, on the basis of quotations and values at the time of the tests, the inducement in the price paid to the farmer for the production of high-grade cotton was not commensurate with the greater value to the manufacturer of the product derived from such cotton.

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A. C. TRUE, Director

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# COURSES IN SECONDARY AGRICULTURE FOR SOUTHERN SCHOOLS.[1]

## (THIRD AND FOURTH YEARS.)

By H. P. BARROWS, *Specialist in Agricultural Education.*

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## INTRODUCTION.

The following outlines are the result of a demand for a more uniform standard in agricultural instruction in secondary schools of the South. The courses outlined, with other elective courses suggested, are intended for the third and fourth years, after the students have completed the work in agronomy and animal husbandry outlined for the first two years.

## ADAPTATION TO LOCAL NEEDS.

It is to be expected that these courses will be molded to meet the needs of the students of each school and the community in which they live. In order to accomplish this purpose it may be necessary to change the order of the courses in the curriculum. To meet the needs of the majority of schools the following order has been suggested: First year, soils and crops; second year, animal husbandry;[2]

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[1] Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education.

[2] See U. S. Dept. Agr. Bul. 521 for courses for the first and second years.

third year, horticulture; fourth year, rural economics and farm management and rural engineering. It is not essential that this order shall be maintained in all cases. In districts where fruit growing or vegetable gardening are the predominating agricultural industries, it may be preferable to have horticulture in the first year and let the students learn the fundamentals of plant production in their application to fruit growing, vegetable gardening, and floriculture.

The topics within each course and their order of presentation must be adapted also to meet local needs. It is left with the local teacher to work out a seasonal sequence where such is desired. The teacher also should emphasize topics of local importance at the expense of those not having local value. For example, lesson outlines cover both grapes and strawberries. It may happen that strawberries are very important in a section to which grapes are not suited; as it will not be necessary to spend much time with grapes, more time will be available for strawberries. Likewise, with more comprehensive subjects the needs of the local community should receive the most consideration.

It must be left with the local teacher also to adapt the courses to the individual needs and capacities of his students. Students who have had a course in botany and a course in crop production will be able to go deeper into a subject like plant breeding than will those who are just beginning these studies. Students who have had shop-work in their elementary courses and mathematics and physics in their high-school course will be capable of more advanced work in rural engineering than students without such preparation.

## ELECTIVE COURSES.

Although something may be done within a given course to meet the needs of a community or a special group of students, it may be necessary to modify an entire curriculum in order to accomplish this purpose successfully. After the students have a foundation in the fundamentals of crop production and animal husbandry, which are needed in all sections, their work may be conducted along more special lines. While it is presumed that all students will need farm management and rural engineering, the school may not be prepared to do justice to these courses as it would to some other branches of agriculture. Wherever it is possible a number of elective courses should be offered in the third and fourth years. In order to do justice to extra courses, where there is but one teacher, it will be necessary to combine classes and offer some of the courses in alternate years. From the following suggested courses it should be possible to make a selection which will meet most conditions in the South:

*Field crops, ½ unit.*—A special course in field crops should be an outgrowth of the general course in soils and crops. The course should be centered around the most important crops in the community. In some sections it may be made largely a course in forage crops, with emphasis on the legumes. In other sections it may be made largely a course in corn or in cotton or both of these crops.

*Animal husbandry, ½ unit.*—This course should be developed from the general course in animal husbandry and should go into a more detailed and thorough consideration of those phases of animal husbandry most important in the community. In most sections it will be largely a course in meat production, with emphasis on swine and beef cattle.

*Dairy husbandry, ½ unit.*—A special course in dairying should not be attempted unless there is provision for practical work in the care of milk and the making of butter and cheese. The course should cover milk production as well as the handling of milk and its products. It should be built upon the elementary lessons given in connection with the general course in animal husbandry. At least half the time should be given to practical work in the dairy.

*Poultry husbandry, ½ unit.*—This course also may be based on the lessons in the animal-husbandry course. A special course not only will give opportunity for a more thorough consideration of those phases of poultry keeping most important in the community, but also time for more practical work.

*Dry farming, ½ unit; irrigation farming, ½ unit.*—These courses are suggested as a means of adapting the work in agriculture to the arid sections of the Southwest. There are textbooks which may be made the bases for both courses.

*Fruit growing, ⅓ unit; vegetable gardening, ⅓ unit; floriculture and landscape gardening, ⅓ unit.*—The general course in horticulture outlined in this bulletin may be divided into three special courses as suggested. The course may be given as a whole or in part, according to the needs of the school. If the work in plant propagation is given with the floriculture and home-ground improvement as outlined, each course will constitute a third of a unit.

*Farm forestry, ¼ unit.*—In many sections a brief course in farm forestry should be given either in addition to the course in horticulture or in substitution for that part not so important in the district. There are good books and bulletins upon which to base the course.

*Insect pests, ¼ unit.*—In connection with the courses in horticulture and field crops in some sections it will be desirable to give special attention to insect pests. Although, as a means of understanding how to control them, it will be essential to know the structure, habits, and life histories of the insects most important in the district, emphasis should be placed upon control measures.

## USE OF REFERENCE MATERIAL.

Although it is left with the teacher and the local school authorities as to whether a textbook is used or not, it is hoped that the outlines, with the references given, will aid the teacher in getting away from the limitations of any one textbook. A list of books suitable for reference purposes is given at the end of each course. By a judicious selection of reference material and the making of special assignments to individual students, the teacher may do much toward adapting the subject to the needs of the community and the members of the class. Special reference to bulletins of the United States Department of Agriculture are given with nearly every lesson. In order to meet local needs, the publications of the States should be used in addition to department publications. It is especially important that the teacher get in touch with the agricultural college, experiment stations, and board of agriculture of the State in which the school is located and learn what material suitable for use in the school may be available. Files of these publications should be kept in working order along with the Yearbooks and the Farmers' Bulletins[1] of the Department of Agriculture.

## USE OF ILLUSTRATIVE MATERIAL.

It is important that concrete material shall be brought into the classroom and that well-organized field trips shall be taken when convenient. In addition to such study, abundant use should be made of pictures, charts, lantern slides, etc., to visualize the lesson in an effective manner. Suggestions for illustrative material are given in connection with many of the lessons. The instructor should make preparations early for all illustrative material needed.[2]

## PRACTICAL WORK.

In the preparation of the outlines, it has been assumed that there will be in the school year 36 weeks of 5 days each. For each year 104 lessons are planned which provide for classroom work three days in the week, leaving four periods for examinations or reviews. The remainder of the time, equal to two periods per day, two days in the week, should be given to practicums and projects. It is assumed that credit will be given for home projects and practicums on the same basis as for laboratory work, i. e., one hour's credit for two hour's work, and that extra credit will be given for extensive projects requiring more than the time needed to make up the credit given for the course. Routine work involved in a project may not be worthy of full credit. It is expected that extra credit will be given for the projects suggested in connection with the fourth-year courses. It is even more important that the practical work meet the needs of the students and the community than that of the classroom. The practicums and projects listed are but suggestive. Credit should be given for any line of community or home work which may involve the acquiring of skill and in which the principles learned in the classroom may be applied. It is especially important that the teacher make an effort to secure acceptable substitutes for home projects for students who do not live on farms. Credit should be given according to the educational value of such work. In order to have such value, it must present problems new to the student, it should be linked in a definite way with the course taken, and it should have the supervision of the instructor or some competent person.[1]

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[1] Farmers' Bulletin and Yearbooks of the United States Department of Agriculture may be obtained free as long as the supply lasts, on application to the Secretary of Agriculture, Washington, D. C., or to a Senator or Representative in Congress. These and other publications of the Department of Agriculture, when no longer available for free distribution, may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at a nominal price. Price lists covering various Government publications may be obtained free from the Superintendent of Documents. Each teacher should secure a copy of Price List No. 16, which includes Farmers' Bulletins, Yearbooks, and Department Bulletins of the United States Department of Agriculture. Lists of these publications prepared for teachers may be obtained from the Agricultural Instruction division of the States Relations Service.

[2] See the following Farmers' Bulletins: 586, Collection and Preservation of Plant Material for Use in the Study of Agriculture; 606, Collection and Preservation of Insects and Other Material for Use in the Study of Agriculture.

## OUTLINE FOR HORTICULTURE—THIRD YEAR.

(One unit.)

### PLANT PROPAGATION.

(Eleven lessons, eight double periods for practical work.)

References.—The Propagation of Plants, Farmers' Bulletin 157. For suggestions as to teaching this subject, with directions for practical work, see States Relations Service Document 63, The Propagation and Pruning of Plants—Suggestions for Teaching the Subject in Secondary Schools.

LESSON 1.—*The Seed.*

1. How plants produce seed.
2. Why plants produce seed.
3. Structure and classification of seeds.

Illustrative material.—Charts and diagrams showing fecundation of the ovule. Flowers and seeds of different types.

LESSON 2.—*Seed Selection.*

1. Factors influencing quality of seed.
2. Importance of seed selection.
3. Gathering and storing seed.
4. Seed buying.

Special references.—The Farmer's Interest in Good Seed, Farmers' Bulletin 111. Articles in the following Yearbooks of the Department of Agriculture: 1896, Seed Production and Seed Saving; 1899, Seed Selling, Seed Growing, and Seed Testing; 1901, Agricultural Seeds, Where Grown and How Handled; 1907, Art of Seed Selection and Breeding; 1915, How Seed Testing Helps the Farmer.

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[1] For a discussion of the home-project plan and the problem of giving credit for home work, see the following bulletins of this department: 346, Home Projects in Secondary Courses in Agriculture; 385, School Credit for Home Practice in Agriculture.

### EXERCISE 1.—*Examination of Seed for Impurities.*

Special reference.—Testing Farm Seed in the Home and in the Rural School, Farmers' Bulletin 428.

### LESSON 3.—*Germination and Testing of Seeds.*

1. Conditions essential to germination.
2. Importance of seed testing.
3. Methods of testing seeds.

Special reference.—Testing Farm Seed in the Home and in the Rural School, Farmers' Bulletin 428.

### EXERCISE 2.—*Testing Seeds for Viability.*

NOTE.—If the students have had some practice in testing farm seed, use garden seeds, such as onion, carrot, and parsnip, or flower seeds more difficult to test.

### LESSON 4.—*The Hotbed.*

1. Principles and essentials of construction.
2. Materials and methods of construction.
3. Management.

Illustrative material.—Diagrams and plans showing hotbed construction.

### EXERCISE 3.—*Hotbed Construction.*

Special reference.—For directions for making a hotbed see Farmers' Bulletin 195, Annual Flowering Plants.

### LESSON 5.—*The Seed Bed and Cold Frame.*

1. Purpose of the seed bed.
2. Establishing and maintaining the bed.
3. Seed flats and their use.
4. The cold frame.
5. The lath house.

Special reference.—Frames as a Factor in Truck Growing, Farmers' Bulletin 460.

### EXERCISE 4.—*Making and Using Seed Flats, Frames, etc.*

### LESSON 6.—*Asexual Propagation.*

1. Underlying principles.
2. Advantages to the farmer.
3. Advantages to the plant breeder.
4. Natural methods.

### LESSON 7.—*Propagation by Parts Intact.*

1. Suckers.
2. Stolons.
3. Layers.
4. Division of the crown.

Illustrative material.—Fresh material supplemented by charts to show various means of propagation.

### LESSON 8.—*Propagation by Parts Detached.*

1. Specialized buds as bulbs, bulblets, corms, and tubers.
2. Roots.
3. Cuttings of various types.

### EXERCISE 5.—*Propagation by Cuttings.*

Lesson 9.—*Budding and Grafting.*

1. Definition.
2. Underlying principles.
3. Essential requisites.

Lesson 10.—*Budding and Grafting*—Continued.

1. Types of budding.
2. Types of grafting.
3. Materials and methods.

Exercise 6.—*Field Practice in Budding.*

Exercise 7.—*Practice in Simple Types of Grafting.*

Lesson 11.—*Nursery and Orchard Practices.*

1. Methods used in producing nursery stock.
2. Methods used in trying out new varieties.
3. Bridge-grafting wounded trees.
4. Top-working established orchards.

Special references.—Farmers' Bulletin 539, The Propagation of Citrus Trees in the Gulf States. Yearbook 1902, Top-working Orchard Trees.

Note.—This lesson may be supplemented to good advantage by a field trip to an orchard or nursery where such work is in progress.

## FRUIT GROWING.

(Thirty-five lessons, 12 double periods for practical work. Projects.)

References.—The following Farmers' Bulletins; 113, The Apple and How to Grow It; 154, The Home Fruit Garden, Preparation and Care; 482, The Pear and How to Grow It; 538, Sites, Soils and Varieties of Citrus Groves in the Gulf States; 631, 632, and 633, Growing Peaches; 700, Pecan Culture; 776, Growing Cherries East of the Rocky Mountains. Articles in the following Yearbooks: 1900, Commercial Pear Culture; 1901, The Home Fruit Garden. Commercial Apple Growing; 1902, Cultivation and Fertilization of Peach Orchards.

Lesson 1.—*Factors Determining Success in Fruit Growing.*

1. Relation to general farming and live stock.
2. Climate and weather conditions.
3. Accessibility to markets.
4. The personal factor.

Illustrative material.—Illustrated Lecture on Orchard Management, States Relations Service, Office of Farmers' Institutes.

Lesson 2.—*The Location and Site for the Orchard.*

1. Soils and subsoils.
2. The moisture supply and water drainage.
3. Temperatures and air drainage.
4. Wind protection.
5. Exposure and slope.

Lesson 3.—*Classification of Fruits.*

1. Pome fruits, stone fruits, citrus fruits, and other fruits of the orchard.
2. Small fruits and grapes.
3. Other fruits.

Lesson 4.—*Varieties of Fruits for the South.*

1. Varieties of general importance.
2. Varieties of local importance or value.

Special references.—Fruits Recommended by American Pomological Society for Cultivation in Various Sections of the United States and Canada. Revised by Committee of American Pomological Society. Bureau of Plant Industry Bulletin 151. "Promising New Fruits" in each of the Yearbooks. Apples: Production Estimates and Important Commercial Districts and Varieties, Department Bulletin 485.

Lesson 5.—*Orchard Soils.*

1. Relation of soils to types of fruit.
2. Relation of soils to varieties of fruit.
3. Relation of soils to water supply.
4. Relation of soils to tillage and management.

Lesson 6.—*Preparing the Land.*

1. Necessity of thorough preparation before planting.
2. Lands to be irrigated or needing drainage.
3. Preparation of new lands.
4. Plowing, subsoiling, and other operations.

Lesson 7.—*Laying out the Orchard.*

1. Distances to plant.
2. Systems of orchard planting.
3. The question of interplanting.
4. Staking out the orchard.

Illustrative material.—Charts showing planting systems.

Lesson 8.—*Planting the Trees.*

1. Time of planting.
2. Care of trees before planting.
3. Details which mean much in planting.
4. Planting implements and methods.

Exercise 1.—*Planting Orchard Trees.*

On the school farm, the home farm of the students, or upon farms neighboring the school.

Lesson 9.—*Cultivation of the Orchard.*

1. Purposes of tillage.
2. Tillage implements.
3. Methods of cultivation.

Lesson 10.—*Green Manures and Cover Crops.*

1. Clean tillage *v.* sod.
2. Value of special crops for green manuring.
3. The problem of erosion and the use of cover crops.
4. Suitable crops and their management.

Lesson 11.—*Fertilizers.*

1. Effects of fertilizers upon trees and fruits.
2. Use of barnyard manure.
3. Commercial fertilizers and their application.

Illustrative material.—Samples of commercial fertilizers.

LESSON 12.—*Intercropping.*

1. Advantages of intercropping.
2. Dangers of intercropping.
3. Poor crops to grow between trees.
4. Good crops and their management.

LESSON 13.—*Friends and Foes of the Fruit Grower.*

1. Birds in the orchards.
2. Work of the honeybee.
3. Extent of insect injury.
4. Extent of losses from disease.
5. Other orchard pests.

Special references.—The following Farmers' Bulletins: 506, Food of Some Well-known Birds of Forest, Farm and Garden; 630, Some Common Birds Useful to the Farmer; 670, Field Mice as Farm and Orchard Pests; 702, Cottontail Rabbits in Relation to Trees and Farm Crops.

LESSON 14.—*Insect Pests and Their Control.*

1. Classification of insects according to nature of injury and method of control.
2. Control of sucking insects.
3. Control of biting and boring insects.
4. Natural enemies of insects.
5. Value of clean cultivation and sanitation.

Illustrative material.—Mounted insects and specimens showing insect injury.

Special reference.—Collection and Preservation of Insects and Other Materials for Use in the Study of Agriculture, Farmers' Bulletin 606.

EXERCISE 2.—*Mixing Insecticides.*

For spraying exercise to follow. May be necessary to combine Exercises 2 and 3.

LESSON 15.—*Some Common Insect Pests.*

1. Insects attacking the pome fruits.
2. Insects attacking the stone fruits.
3. Miscellaneous insects of importance.

Special references.—The following Farmers' Bulletins: 440, Spraying Peaches for the Control of Brown Rot, Scab, and Curculio; 492, The More Important Insect and Fungus Enemies of Fruit and Foliage of the Apple; 650, San Jose Scale and Its Control; 662, Apple Tree Tent Caterpillar; 675, Round-headed Apple Tree Borer; 723, Oyster-shell Scale and the Scurfy Scale; 845, Gipsy Moth and Brown-tail Moth. The following circulars of the Bureau of Entomology; 20, The Wooly Aphis of the Apple; 54, The Peach Tree Borer; 131, How to Control Pear Thrips. Articles in the following Yearbooks: 1907, Codling Moth or Apple Worm; 1908, Information About Spraying for Orchard Insects; 1913, Bringing Applied Entomology to the Farmer.

EXERCISE 3.—*Spraying for Insect Pests.*

Wherever possible this should be a class practicum upon the school farm or farms neighboring the school. If the school does not own a spraying outfit it may be possible to borrow one. It is preferable to spray where the work is really needed and with a view of accomplishing practical results. If it is impossible to carry out spraying as a class practicum it should be encouraged as a home practicum.

Special reference.—Important Insecticides, Farmers' Bulletin 127.

### LESSON 16.—*Plant Diseases.*

1. Physiological troubles.
2. Fungus parasites.
3. Bacteria and plant disease.

Illustrative material.—Mounted specimens showing plant diseases.

Special reference.—Collection and Preservation of Plant Material for Use in the Study of Agriculture, Farmers' Bulletin 586.

### LESSON 17.—*The Control of Plant Diseases.*

1. Value of sanitation and general preventive measures.
2. Disease-resistant varieties.
3. Spraying and pruning as a means of control.

Special references.—The following Farmers' Bulletins: 243, Fungicides and Their Use in Preventing Diseases of Fruits; 284, Insect and Fungus Enemies of the Grape East of the Rocky Mountains; 440, Spraying Peaches for Control of Brown Rot, Scab, and Curculio; 492, The More Important Insect and Fungus Enemies of the Fruit and Foliage of the Apple. Articles in the following Yearbooks: 1895, Cause and Prevention of Pear Blight; 1896, Diseases of Shade and Ornamental Trees; 1908, Development of Farm Crops Resistant to Disease.

### EXERCISE 4.—*Mixing Fungicides.*

The suggestions for mixing insecticides and spraying for insect pests will apply to Exercises 4 and 5.

### LESSON 18.—*Some Common Diseases of Orchard Fruits.*

1. Diseases attacking the pome fruits.
2. Diseases attacking the stone fruits.
3. Miscellaneous diseases of importance.

Special references.—The following Farmers' Bulletins: 243, Fungicides and Their Use in Preventing Diseases of Fruits; 440, Spraying Peaches for the Control of Brown Rot, Scab, and Curculio; 492, The Important Insect and Fungus Enemies of the Fruit and Foliage of the Apple. Peach Scab and Its Control, Department Bulletin 395.

### EXERCISE 5.—*Spraying for Fungus Diseases.*

### LESSON 19.—*Frost Protection.*

1. Physics of frost formation.
2. Foretelling frost.
3. Injury due to freezing temperatures.
4. Methods of protection and control.

Special references.—Articles in the following Yearbooks: 1909, Prevention of Frost Injury to Fruit Crops; 1914, Story of the Thermometer and Its Uses in Agriculture. The following Farmers' Bulletins: 104, Notes on Frost; 401, Protection of Orchards in the Pacific Northwest from Spring Frosts by Means of Fires and Smudges.

### LESSON 20.—*Principles of Pruning.*

1. A study of fruit buds.
2. Bearing habits of trees.
3. Pruning for wood *v.* pruning for fruit.
4. Pruning tools.

Special references.—Articles in the following Yearbooks: 1895, Principles of Pruning and Care of Wounds in Woody Plants; 1898, Pruning of Trees and Other Plants. Pruning, Farmers' Bulletin 181.

LESSON 21.—*Pruning Young Trees.*

1. Directing the growth.
2. Pruning the young tree which has been neglected.
3. Special directions for forming heads on trees of different types.

EXERCISE 6.—*Pruning Young Trees.*

Inasmuch as pruning is largely an art involving skill to be developed by practice, as much time as possible should be spent in the application of the principles discussed in the classroom in practical work in the orchard. In any fruit-growing community it should not be difficult to secure material for practice near the school. Although the work may be introduced by a demonstration from the instructor and should be supervised closely, its value will depend largely upon the amount of practice secured by each individual student. Usually it is not necessary for the school to own equipment for all the students, as they may bring tools from home. For young trees hand shears will suffice, but for older trees saws, long-handled shears, and ladders also will be needed.

LESSON 22.—*Pruning Trees in Bearing.*

1. Relation of pruning to fruit production.
2. Special directions for pruning different kinds of trees in bearing.

EXERCISE 7.—*Pruning Bearing Trees.*

LESSON 23.—*Renovating Old Orchards.*

1. Possibilities in renovation.
2. Pruning, spraying, scraping, cultivation, and other operations involved.
3. Top-working to change variety.

Special reference.—The Profitable Management of the Small Apple Orchard on the General Farm, Farmers' Bulletin 491.

EXERCISE 8.—*Pruning Neglected Trees.*

LESSON 24.—*Strawberries.*

1. The botany of the strawberry plant.
2. Soils and fertilizers for strawberries.
3. Establishing the strawberry bed.
4. Care and cultivation.

Special references.—The following Farmers' Bulletins: 198, Strawberries; 664, Strawberry Growing in the South.

LESSON 25.—*Bush Fruits.*

1. Raspberries.
2. Blackberries and dewberries.
3. Currants.
4. Gooseberries.

Special references.—The following Farmers' Bulletins: 213, Raspberries; 643, Blackberry Culture; 728, Dewberry Culture. Small Fruit Culture for Market, Yearbook 1895.

LESSON 26.—*Grapes.*

1. Species of grapes.
2. Propagation of the grape.
3. Establishing a vineyard.
4. Care and management.
5. Enemies.

Special references.—Pruning and Training of Grapes, Yearbook 1898. The following Farmers' Bulletins: 118, Grape Growing in the South; 471, Grape Propagation, Pruning, and Training; 709, Muscadine Grapes; 758, Muscadine Grape Sirup.

### LESSON 27.—*Picking Fruit.*

1. When to pick.
2. How to pick.
3. Picking equipment.
4. Management of pickers.

### EXERCISE 9.—*Picking Fruit.*

The picking, packing, and grading of fruits is another form of practice which must be adapted to community needs and community interests. In one section the work may be centered on strawberries, in another apples, and perhaps in a third it will be citrus fruits. Exercises 9, 10, and 11 may be combined and as much extra time devoted to the work as possible. In this work also demonstrations may very well precede practice. Perhaps some of the students are so skilled that they may show other students how.

Special reference.—Color as an Indication of the Picking Maturity of Fruits and Vegetables, Yearbook 1916.

### LESSON 28.—*Grading Fruit.*

1. Necessity for grading.
2. Examples of standard grading.
3. Packages.

Illustrative material.—Charts showing systems of grading and packing.

### LESSON 29.—*Packing.*

1. Packing small fruits.
2. Packing apples and pears.
3. Packing plums and apricots.
4. Packing peaches.
5. Packing cherries.

### EXERCISES 10 AND 11.—*Grading and Packing Fruits.*

### LESSON 30.—*Storing Fruits.*

1. Keeping qualities of fruits.
2. Relation of keeping quality to handling.
3. Advantages in storing.
4. Essentials of good storage.
5. Types of storehouses.

Special reference.—Cold Storage of Small Fruits, Bureau of Plant Industry Bulletin 108.

### LESSON 31.—*Transportation of Fruits.*

1. Relation of distance of market to type of fruit growing.
2. Facilities for quick handling.
3. Hauling to near-by markets.
4. Express shipments.
5. Loading cars.
6. Precooling and refrigeration.

### LESSON 32.—*Marketing.*

1. The fruit market as it now exists.
2. Building up a private trade.
3. Cooperative marketing.
4. Advertising.

Special references.—Handling and Shipping Citrus Fruits in the Gulf States, Farmers' Bulletin 696. Articles in the following Yearbooks: 1905, Handling of Fruit for Transportation; 1910, Cooperation in Handling and Marketing Fruit; 1910, Precooling of Fruit.

### EXERCISE 12.—*A Fruit Exhibit. Judging Fruits.*

Special references on plant breeding.—The following Bulletins of the Bureau of Plant Industry: 167, New Methods of Plant Breeding; 165, Application of Some of the Principles of Heredity to Plant Breeding. Articles in the following Yearbooks: 1897, Hybrids and Their Utilization in Plant Breeding; 1898, Improvement of Plants by Selection; 1899, Progress of Plant Breeding in the United States; 1901, Progress in Plant and Animal Breeding; 1910, New Methods of Plant Breeding; 1911, Plant Introduction for the Plant Breeder.

### LESSON 33.—*Improvement of Fruits.*

1. Law of variation.
2. Law of heredity.
3. Selection—natural and artificial.

### LESSON 34.—*Improvement of Fruits*—Continued.

1. Methods of increasing variation.
2. Selection according to ideals.
3. Testing hereditary powers.
4. Relation to methods of propagation.

### LESSON 35.—*Improvement of Fruits*—Continued.

1. Some things which have been accomplished by plant breeders.
2. Future possibilities.
3. Work of farmer *v.* work of specialist.

Suggested Home Projects—

1. Care and management of bearing orchard.
2. Establishing of home orchard.
3. Renovation of old orchard.[1]
4. Ridding orchards of insect pests and diseases.
5. Top-working trees to more desirable varieties.
6. Harvesting and marketing fruit crops.
7. Production projects with strawberries and other small fruits.

Suggestions for Group Projects—

If the school owns a farm upon which an orchard is located, the class in fruit growing might be given the care and management of the school orchards as a means of applying their classroom instruction and for securing practical experience upon which to base the instruction of the classroom. Some successful schools which have not owned orchards have leased neighboring orchards and turned their management over to the students in horticulture, who did all the work under the direction of the teacher. As the class was responsible for the success of the project, financially and otherwise, such an undertaking proved an excellent method of developing cooperation and group action among the students.

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[1] See Department Bulletin 346, Home Projects in Secondary Courses in Agriculture, for outline of this project.

### HOME FLORICULTURE.

(11 lessons. Projects.)

Reference.—See States Relations Service Document 54, Home Floriculture—Suggestions for Teaching the Subject in Secondary Schools.

This document gives an outline for a home flower garden project and suggestions for practicums. Although no time is allowed in this outline for practice, it may be possible in some cases to take more time for this work at the expense of some other part of the course not so important in the community.

LESSON 1.—*How Plants Grow.*

1. Requirements of the plant.
2. Work of roots, stems, and leaves.
3. The blooming of plants.

LESSON 2.—*How We May Aid Plants in Growing.*

1. Meeting requirements for food, water, air, light, and proper temperature.
2. Protection from enemies.

LESSON 3.—*Soils and Fertilizers for Flowering Plants.*

1. Ideal garden soils.
2. Modifying unsuitable types.
3. Bedding and potting soils.
4. Natural manures—the compost heap.
5. Commercial fertilizers.

LESSON 4.—*Treatment for Insects and Disease.*

1. Classes of insects and their injury.
2. Methods of insect control.
3. Types of plant disease.
4. Control of disease.

Illustrative material.—Specimens of insects and plant diseases affecting flowering plants.

LESSON 5.—*Annuals.*

1. The plants.
2. Their management.

Special reference.—Annual Flowering Plants, Farmers' Bulletin 195.

Illustrative material.—In considering the various classes of flowering plants fresh material from the garden should be used where it may be obtained. Good illustrations, such as found in magazines and the best catalogues, should be used in a supplementary way.

LESSON 6.—*Potting and Bedding Plants.*

1. Plants suitable for potting.
2. Potting the plants.
3. Management of potted plants.

LESSON 7.—*Herbaceous Perennials.*

1. The plants.
2. Their management.

LESSON 8.—*Bulbs.*

1. The plants.
2. Their management.

LESSON 9.—*Roses and Other Woody Perennials.*

1. Types and varieties of roses.
2. Management of roses.
3. Other woody perennials of local importance.

Special reference.—Roses for the Home, Farmers' Bulletin 750.

LESSON 10.—*Window Gardening.*

1. The essentials of a window box.
2. Making window boxes.
3. Suitable plants and their management.

Illustrative material.—There are great possibilities in the use of window boxes to furnish living material for a study of plants in the classroom.

LESSON 11.—*The Home Flower Garden.*

1. Purpose of the garden.
2. Location.
3. Plans.
4. Management.

Suggested projects.—

1. Care and management of home flower garden.
2. Contests in growing special plants suited to locality.
3. Producing plants or flowers for sale.
4. Trying out plants little known in community.
5. An exhibit of flowers grown.

### HOME-GROUND IMPROVEMENT.

(11 lessons. Projects.)

References.—Beautifying the Home Grounds, Farmers' Bulletin 185. See States Relations Service Document 54, Improving the Home Grounds—Suggestions for Teaching the Subject in Secondary Schools, for directions for practicums and projects to accompany these lessons. A project-study outline is given.

LESSON 1.—*Landscape Art Applied to the Home.*

1. Principles same as applied to large areas.
2. The fundamentals of landscape art.
3. Horticultural knowledge required.

Illustrative material.—Photographs and pictures from magazines will do much toward establishing ideals in landscape art in the minds of the students.

LESSON 2.—*Planning the Home Grounds.*

1. Ideal plans.
2. Meeting existing conditions.
3. Country *v.* city homes.

Illustrative materials.—Charts and blackboard diagrams showing plans should be used in connection with this lesson. Illustrated lecture, Farm Home Grounds: Their Planting and Care, States Relations Service, Office of Farmers' Institutes.

LESSON 3.—*Beds, Walks, and Drives.*

1. Place in the plan.
2. Construction and management.

LESSON 4.—*Lawns.*

1. Lawn soils and fertilizers.
2. Grasses for lawns.
3. Establishing the lawn.
4. Maintaining the lawn.

Special reference.—Lawn Soils and Lawns, Farmers' Bulletin 494.

LESSON 5.—*Deciduous Trees.*

1. Place of trees on the home grounds.
2. Kinds of trees adapted to local condition.
3. Planting shade trees.
4. Care and management.

Special reference.—Practical Tree Surgery, Yearbook 1913.

LESSON 6.—*Evergreens.*

1. Place of evergreens on the home grounds.
2. Broad-leaved evergreens.
3. The conifers.
4. Planting and management.

LESSON 7.—*Shrubs.*

1. Place of shrubs on the home grounds.
2. Kind of shrubs adapted to local conditions.
3. Planting and management.

LESSON 8.—*Vines.*

1. Place of vines on home grounds.
2. Annual vines.
3. Perennial vines.
4. Planting and management.

LESSON 9.—*Hedges, Shelter, and Windbreaks.*

1. Place on the home grounds.
2. Suitable shrubs and trees.
3. Planting and management.

LESSON 10.—*Temporary v. Permanent Effects.*

1. The new home—getting quick results.
2. Use of quick-growing annuals.
3. Rapid-growing soft wood trees.
4. Replacing with more enduring forms.

LESSON 11.—*The School Grounds.*

1. Need for school-ground ornamentation.
2. School grounds *v.* the home grounds.
3. Planting and managing the school grounds.

Special reference.—Tree Planting on Rural School Grounds, Farmers' Bulletin 134.

Suggested projects.—

1. Ornamenting home grounds completely or in part as: Front and back yard improvement, planting trees, shrubs, hedges, lawns or beds of flowers.
2. Community improvement campaign.
3. Ornamentation of school grounds.

## VEGETABLE GARDENING.

(35 lessons. Projects.)

References.—The following Farmers' Bulletins: 255, The Home Vegetable Garden; 647, The Home Garden in the South. Articles in the following Yearbooks: 1900, Development of Trucking Interests; 1907, Truck Farming in Atlantic Coast States.

LESSON 1.—*Types of Vegetable Gardening.*

1. The home vegetable garden.
2. Market gardening.
3. Truck farming.
4. Seed growing.

LESSON 2.—*Factors Which Influence the Growing of Vegetables.*

1. Relation to general farming.
2. Climate and weather conditions.
3. Accessibility to markets and transportation facilities.
4. The personal factor.

LESSON 3.—*Soils and Their Treatment.*

1. Types of soils best suited for vegetables.
2. Improvement of heavy soils.
3. Improvement of light soils.
4. Preventing erosion.

LESSON 4.—*Barnyard and Green Manures.*

1. Value of organic matter.
2. Care and use of barnyard manure.
3. Management of green-manuring crops.

Special references.—The following Farmers' Bulletins: 192, Barnyard Manure; 278, Leguminous Crops for Green Manuring.

LESSON 5.—*Commercial Fertilizers.*

1. Conditions making use essential and profitable.
2. Buying and mixing of fertilizers.

LESSON 6.—*Garden Tools and Implements.*

1. Tools for preparation.
2. Hand tillage tools.
3. Horse-drawn tillage implements.
4. Planting machines.
5. Harvesting machines.
6. The tool house—care of implements.

Illustrative material.—Implement catalogues. Visit to implement dealer if possible.

LESSON 7.—*Seeds.*

1. Importance of good seed.
2. Viability in relation to age.
3. Germination temperature in relation to time of planting.
4. Testing seeds.

Illustrative material.—Seed catalogues, samples of garden seed.

LESSON 8.—*Seed Growing and Buying.*

1. Home-grown seed.
2. Specialized seed growing.
3. Buying seed.

Special references.—Farmers' Bulletin 884, Saving Vegetable Seeds for the Home and Market Garden. Production of Vegetable Seeds, Bureau of Plant Industry Bulletin 184. Articles in the following Yearbooks: 1896, Seed Production and Seed Saving; 1899, Seed Selling, Seed Growing and Seed Testing; 1901, Agricultural Seeds, Where Grown and How Handled; 1907, Art of Seed Selection and Breeding; 1909, Vegetable Seed Growing as a Business.

LESSON 9.—*Improvement of Varieties.*

1. Work of seed growers and special plant breeders.
2. Selection in connection with home-grown seed.
3. Novelties *v.* proven varieties.
4. Study of seed catalogues.

Special reference.—Testing Commercial Varieties of Vegetables, Yearbook 1900.

LESSON 10.—*General Cultural Methods.*

1. Preparation of the seed bed.
2. Planting methods.
3. Conservation of moisture.
4. Combating weeds.

LESSON 11.—*Garden Insects.*

1. Damage done by insects.
2. Common biting insects of the garden.
3. Common sucking insects of the garden.

Illustrative material.—Specimens of common garden insects.

LESSON 12.—*Control of Insect Pests.*

1. Poison sprays.
2. Contact sprays.
3. Control by rotation.
4. Other means of control.

LESSON 13.—*Control of Diseases.*

1. Nature of plant diseases.
2. Control by spraying.
3. Control by rotation.
4. Other means of control.
5. Disease-resistant varieties.

Illustrative material.—Specimens of diseases of garden crops.

Special references.—The following Farmers' Bulletins: 232, Spraying for Cucumber and Melon Diseases; 488, Diseases of Cabbage and Related Crops and Their Control; 544, Potato Tuber Diseases; 714, Sweet Potato Diseases.

LESSON 14.—*Harvesting and Marketing.*

1. Harvesting of the green crops.
2. Harvesting of matured products.
3. Harvesting devices and machinery.
4. Transportation of vegetables.
5. Establishing a private trade.
6. Cooperative marketing.

Special reference.—A Successful Method of Marketing Vegetable Products, Yearbook, 1912.

LESSON 15.—*Storing Vegetables.*

1. Keeping qualities of vegetables.
2. Essentials of good storage.
3. Devices for storing in the field.
4. The storage house.

LESSON 16.—*Sweet Potatoes.*

1. Botany of the plant.
2. Types and varieties.
3. Soils and fertilizers.
4. Propagation and planting.
5. Cultivation and management of crop.
6. Storage and handling of crop.

(The above outline may be adapted to the crops following.)

Special references.—The following Farmers' Bulletins: 324, Sweet Potatoes; 548, Storing and Marketing Sweet Potatoes; 714, Sweet Potato Diseases.

Illustrative material.—Illustrated lecture, The Sweet Potato: States Relations Service, Office of Farmers' Institutes.

LESSON 17.—*Root Crops.*

1. Radishes.
2. Turnips and rutabagas.
3. Beets.

LESSON 18.—*Root Crops.*

1. Salsify.
2. Carrots.
3. Parsnips.
4. Other roots of local importance.

LESSON 19.—*Irish Potatoes.*

Special references.—The following Farmers' Bulletins: 407, The Potato as a Truck Crop; 533, Good Seed Potatoes and How to Produce Them; 753, Commercial Handling, Grading, and Marketing of Potatoes.

LESSON 20.—*Onions.*

Special references.—The following Farmers' Bulletins: 354, Onion Culture; 434, The Home Production of Onion Seed and Sets.

LESSON 21.—*Cabbage and Its Relatives.*

1. Cabbage and collards.
2. Cauliflower.
3. Kohl-rabi.
4. Brussels sprouts.

Special reference.—Cabbage, Farmers' Bulletin 433.

LESSON 22.—*Plants for Greens and Garnishing.*

1. Kale.
2. Turnips.
3. Mustard.
4. Spinach.
5. Swiss chard.
6. Dandelions.
7. Parsley.
8. Cress and other crops of minor or local importance.

LESSON 23.—*Lettuce and Endive.*

Special reference.—American Varieties of Lettuce, Bureau of Plant Industry Bulletin 69.

LESSON 24.—*Celery.*

Special reference.—Celery, Farmers' Bulletin 282.

Lesson 25.—*Tomatoes, Peppers, and Eggplant.*

Special references.—The following Farmers' Bulletins: 220, Tomatoes; 642, Tomato Growing in the South.

Lesson 26.—*Watermelons.*

Lesson 27.—*Cantaloups and Muskmelons.*

Lesson 28.—*Cucumbers and Squashes.*

Special references.—The following Farmers' Bulletins: 254, Cucumbers; 231, Spraying for Cucumber and Melon Diseases.

Lesson 29.—*Sweet Corn and Popcorn.*

Special references.—The following Farmers' Bulletins: 553, Popcorn for the Home; 554, Popcorn for the Market.

Lesson 30.—*Some Southern Vegetables.*

1. Okra.
2. Globe artichoke.
3. Roselle.

Special references.—The following Farmers' Bulletins: 232, Okra: Its Culture and Uses; 307, Roselle: Its Culture and Uses.

Lesson 31.—*Asparagus and Rhubarb.*

Lesson 32.—*Peas and Beans.*

Special reference.—Beans, Farmers' Bulletin 289.

Lesson 33.—*The Farmers' Vegetable Garden.*

1. Importance of producing vegetables for the home.
2. Plans in relation to economical management.
3. Management.

Illustrative material.—Illustrated lecture, The Home Vegetable Garden, States Relations Service, Office of Farmers' Institutes.

Lesson 34.—*The Suburban Garden.*

1. Kinds of vegetables.
2. Plans in relation to available space.
3. Management.
4. The garden in town and village.

Lesson 35.—*Forcing Vegetables.*

1. The hotbed.
2. Cold frames.
3. Sundry devices.

Special reference.—Frames as a factor in Truck Growing, Farmers' Bulletin 460.

## SUGGESTED PROJECTS FOR HORTICULTURE.

### SCHOOL GARDEN.

1. Wherever the home vegetable garden needs exploitation, the school garden might well be made a model home garden.

2. It may be used for the introduction of new varieties and that students and patrons may secure a wider knowledge of vegetable farms.

3. It may be used to supply vegetables and fruits for the domestic-science work, especially in connection with canning practice.

### HOME GARDENS.

1. Care and management of home vegetable garden.
2. Production projects with acre or less of crop suitable to locality and for which there is a ready market.
3. Correlation with canning-club work.
4. Improvement of varieties by seed selection.
5. Seed-growing experiments.
6. Variety tests.
7. Control of insects and disease.
8. Production and sale of plants grown in hotbeds, etc.
9. Developing city trade through parcel post.
10. An exhibition of products grown.

### EQUIPMENT FOR HORTICULTURE.

As the laboratory work in horticulture is essentially of a practical nature in which the exercises are adapted to local conditions, no definite list of apparatus and materials is possible. The work should be adapted to the resources of the school as well as to its needs. The school which owns a well-equipped farm with greenhouse, orchard, and garden will have the advantage; however, no school need neglect practical work because it does not have equipment, as it may use the home farms of the students and the farms surrounding the school.

Each school should make an effort to secure the following equipment for the exercises suggested in the outline:

Materials for hotbed, cold frames, seed flats, and window boxes.

Budding knives, grafting chisel, pruning saws, and shears.

Material for making grafting wax.

A spraying outfit with spraying materials for insect pests and plant diseases.

A collection of vegetable and flower seeds, with blotters and paper pie plates to be used in testing.

### TEXTS AND REFERENCES FOR HORTICULTURE.[1]

Bailey, L. H. Manual of Gardening. New York: The Macmillan Co., 1914, 2. ed.
Bailey, L. H. The Pruning Book. New York: The Macmillan Co., 1911, 12. ed.
Bailey, L. H. The Principles of Fruit Growing. New York: The Macmillan Co., 1915, rev. ed.
Bailey, L. H. The New Standard Cyclopedia of Horticulture. 6 Vols. New York, The Macmillan Co. Vols. I and II, 1914; Vol. III, 1915; Vols. IV and V, 1916; Vol. VI, 1917.
Bailey, L. H., and Gilbert, A. W. Plant Breeding. New York: The Macmillan Co., 1915, rev. ed.
Brown, R. S. Modern Fruit Marketing. New York: Orange Judd Co., 1917.
Card, F. W. Bush Fruits. New York: The Macmillan Co., 1917, rev. ed.
Davenport, Eugene. Domesticated Annuals and Plants. Boston: Ginn & Co., 1910.

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[1] These books are recommended by the Commission on Accredited Schools of the Southern States.

Duggar, B. M. Fungous Diseases of Plants. Boston: Ginn & Co., 1909.

Card, F. W. Bush Fruits. New York: The Macmillan Co., 1914.

Corbett, L. C. Garden Farming. Boston: Ginn & Co., 1914.

Goff, E. S. The Principles of Plant Culture. New York: The Macmillan Co., 1916, rev. ed.

Green, S. B. Popular Fruit Growing. St. Paul, Minn.: Webb Pub. Co., 1912, 4. ed. rev.

Green, S. B. Vegetable Gardening. St. Paul, Minn.: Webb Publishing Co., 1914, 12. ed. rev.

Kains, M. G. Plant Propagation. New York: Orange Judd Co., 1916.

Lloyd, J. W. Productive Vegetable Gardening. Philadelphia: J. B. Lippincott Co., 1914.

Lodeman, E. G. The Spraying of Plants. New York: The Macmillan Co., 1910.

Rexford, E. E. Home Floriculture. New York: Orange Judd Co., 1903.

Rolphs, P. H. Subtropical Vegetable Gardening. New York: The Macmillan Co., 1916.

Sears, F. C. Productive Orcharding. Philadelphia: J. B. Lippincott Co., 1914.

Slingerland, M. V., and Crosby, C. R. Fruit Insects. New York: The Macmillan Co., 1914.

Smith, J. B. Economic Entomology. Philadelphia: J. B. Lippincott Co., 1906.

Watts, R. L. Vegetable Gardening. New York: Orange Judd Co., 1912.

Waugh, F. A. Landscape Gardening. New York: Orange Judd Co., 1912.

Weed, C. M. Farm Friends and Farm Foes. Boston: D. C. Heath & Co., 1910.

White, E. A. Principles of Floriculture. New York: The Macmillan Co., 1915.

## OUTLINE FOR RURAL ENGINEERING—FOURTH YEAR.

(One-half unit.)

General references.—How Engineering May Help Farm Life, Yearbook 1915. Laboratory Exercises in Farm Mechanics for Agricultural High Schools, Farmers' Bulletin 638.

### FARM MACHINERY.

(24 lessons, 16 exercises.)

LESSON 1.—*Development of Farm Machinery.*

1. History of agriculture in relation to machinery.
2. Development of particular types.
3. Status of American farming in relation to machinery.

LESSON 2.—*Relation of Farm Machinery to Management.*

1. Equipment in relation to type of farming.
2. Equipment in relation to size of farm.
3. Buying machinery.

Special references.—Minor Articles of Farm Equipment, Bureau of Plant Industry, Circular 44. Study of Farm Equipment in Ohio, Bureau of Plant Industry, Bulletin 213.

LESSON 3.—*Mechanical Principles.*

1. Definitions of machine, implement, and tool.
2 Physical principle involved.
3. Factors of efficiency.

LESSONS 4 AND 5.—*Tillage Implements.*

1. Deep tillage implements.
    (*a*) The plow and subsoiler.
2. Shallow tillage implements.
    (*a*) Cultivators, (*b*) harrows, (*c*) the roller and planker, and (*d*) weeders.
3. Hand tools.

Illustrative material.—Catalogues of implement dealers.

EXERCISE 1.—*A Study of Tillage Implements.*

The class may spend the time profitably making a first-hand study of the tillage implements on a well-equipped farm or at an implement dealer's. This exercise should involve the naming of parts as suggested in Exercise 23, Farmers' Bulletin 638.

LESSON 6.—*Fertilizing Machines.*

1. The manure spreader.
2. Machines and devices for spreading commercial fertilizers.
3. Lime-spreading machine.

Special reference.—Farm Methods of Applying Land Plaster in Western Oregon and Western Washington, Bureau of Plant Industry Circular 22.

EXERCISE 2.—*Study and Use of Manure Spreader.*

Arrangements may be made with a near-by farmer so that the students not familiar with a manure spreader may have an opportunity to operate one.

LESSON 7.—*Planting Machines.*

1. Grain drills.
2. Hand drills and seeders.

EXERCISE 3.—*Study and Use of Grain Drill.*

Students who have not used a grain drill should be favored in this practice to be secured on a neighboring farm if the school does not own one. This exercise also may involve the calibration of the grain drill as suggested in Exercise 29, Farmers' Bulletin 638.

LESSON 8.—*Planting Machines*—Continued.

1. Corn planters.
2. Potato planters.
3. Miscellaneous planting devices.

EXERCISE 4.—*Study and Use of Corn-planting Machines.*

Each student should be given an opportunity to become familiar with the types of corn planters most successful in the district. See Farmers' Bulletin 638, Exercise 28, Corn Planter Operation.

LESSON 9.—*Hay-making Machines.*

1. Mowers.
2. Rakes and tedders.
3. Loading, stacking, and storing devices.

LESSON 10.—*Grain-harvesting Machines.*

1. The reaper and self-binder.
2. The header.
3. Corn-harvesting machines.

Special reference.—Corn-harvesting Machinery, Farmers' Bulletin 303.

EXERCISE 5.—*Assembling Mowing Machine and Hay Rake.*

See Farmers' Bulletin 638, Exercise 27, Assembling a Machine.

EXERCISE 6.—*Study of Self Binder.*

LESSON 11.—*Potato and Root Diggers.*

1. Potato diggers.
2. Root diggers.

LESSON 12.—*Thrashing Machines.*

1. The grain separator.
2. Special thrashing machines.
3. The cotton gin.

LESSON 13.—*Machines for Preparing Stock Food and Seeds.*

1. Feed mills, grinders and corn shellers.
2. Ensilage and root cutters.
3. Fanning mills.

EXERCISE 7. *Study and Use of Feed and Fanning Mills.*

This exercise may be carried on most profitably on a neighboring farm or at a feed store.

LESSON 14.—*Farm Conveyances.*

1. Wagons and trucks.
2. Lighter vehicles.

LESSON 15.—*Spraying Machinery.*

1. Hand sprayers.
2. Power sprayers.

EXERCISE 8.—*A Study of Spraying Machinery.*

LESSON 16.—*Power on the Farm.*

1. Elementary principles and definitions.
2. Measurement of power.
3. Transmission of power.

LESSON 17.—*Animals as a Source of Power.*

1. The horse, mule, and the ox.
2. Use of the treadmill.

EXERCISE 9.—*Fitting Collars to Horses or Mules.*

See Farmers' Bulletin 638, Exercise 6, Fitting Collars on Horses.

EXERCISE 10.—*Hitching Three or More Horses or Mules.*

See Farmers' Bulletin 638, Exercise 7, Hitching Up One to Four Horses.

EXERCISE 11.—*Repairing Harness.*

See Farmers' Bulletin 638, Exercise 9, Repair of Harness.

LESSON 18.—*Wind as a Source of Power.*

1. Possibilities.
2. Windmills.

Special reference.—Use of Windmills in Irrigation in the Semiarid West, Farmers' Bulletin 394.

LESSONS 19 AND 20.—*The Gasoline Engine.*

1. Construction.
2. Types of engines.
3. Uses.
4. General problems of operation.

Special reference.—The Use of Alcohol and Gasoline in Farm Engines, Farmers' Bulletin 277.

EXERCISE 12.—*Study of the Gasoline Engine.*

See Farmers' Bulletin 638, Exercise 10, Naming Parts of Gas Engine, and Exercise 11, Wiring Engine.

LESSON 21.—*Stationary Engines and Their Use.*

1. Selecting an engine.
2. Arrangement of mills, etc.
3. Connection of machines.
4. Operation.

EXERCISE 13.—*Use of Gasoline Engine.*

See Farmers' Bulletin 638, Exercise 12, Running Gas Engine, and Exercise 13, Troubles on Gas Engine.

LESSON 22.—*Traction Engines and Automobiles.*

1. Use of the tractor upon the farm.
2. Types of traction engines.
3. The automobile on the farm.

Special references.—Farm Experience with the Tractor, Department Bulletin 174. An Economic Study of the Farm Tractor in the Corn Belt, Farmers' Bulletin 719.

EXERCISES 14 AND 15.—*Study and Use of Automobile.*

Students who know how to operate an automobile should aid the instructor in teaching those not familiar with the machine.

LESSON 23.—*Care of Farm Machinery.*

1. Importance of good care.
2. Details of care.

LESSON 24.—*Repair of Farm Machinery.*

1. The farm shop and its equipment.
2. Utilization of winter season.
3. Importance of supply of extras and repair material.
4. Utilization of material on the farm.

Special reference.—The Repair of Farm Equipment, Farmers' Bulletin 347.

EXERCISE 16.—*Listing Repairs for Old Machinery.*

See Farmers' Bulletin 638, Exercise 26, Making List of Repairs for Machine.

## FARM STRUCTURES.

(10 lessons, 6 exercises.)

Reference.—Farm Architecture, Farmers' Bulletin 126.

LESSON 1.—*Use of Cement and Concrete on the Farm.*

1. For what used.
2. Selection of materials.
3. Mixing of materials.

Special references.—The following Farmers' Bulletins: 235, Cement, Mortar, and Concrete; 403, The Construction of Concrete Fence Posts; 461, The Use of Concrete on the Farm.

EXERCISE 1.—*The Mixing and Use of Concrete.*

See Farmers' Bulletin 638, Exercise 16, Concrete Posts, and Exercise 17, Feeding Floor or Sidewalk.

LESSON 2.—*Arrangement of Farm Buildings.*

1. Points to be considered.
2. Suggestive plans.

LESSON 3.—*Building Materials.*

1. Factors affecting choice.
2. Relation of quality to service.
3. Care of farm buildings.
4. Preservative measures and materials.

Special reference.—Use of Paint on the Farm, Farmers' Bulletin 474.

EXERCISE 2.—*Painting and Whitewashing.*

See Farmers' Bulletin 638, Exercise 22, Painting and Whitewashing

LESSON 4.—*The Farmhouse.*

1. Selection of site.
2. Style of architecture.
3. General plans.

LESSON 5.—*The Farmhouse*—Continued.

1. Planning the farmhouse.
2. Modern conveniences for the farm home.

Illustrative material.—Illustrated lecture on Farm Homes, States Relations Service, Office of Farmers' Institutes.

Special references.—Modern Conveniences for the Farm Home, Farmers' Bulletin 270; Comforts and Conveniences in Farmers' Home, Yearbook 1909.

EXERCISE 3.—*Planning Farmhouses.*

Have each student make an individual plan for a farmhouse of medium size.

LESSON 6.—*Barns and Stables.*

1. General barns.
2. The granary.

LESSON 7.—*Barns and Stables*—Continued.

1. The dairy barn.
2. Hog houses and sheep sheds.

Special references.—Designs for Dairy Buildings, Bureau of Animal Industry Circular 131. Hog Houses, Farmers' Bulletin 438.

EXERCISE 4.—*Planning Barns.*

Have each student plan at least one barn.

LESSON 8.—*Poultry Houses.*

1. Types of poultry houses.
2. Plans.
3. Special coops.

Special reference.—Poultry-house Construction, Farmers' Bulletin 574.

EXERCISE 5.—*Making Hog House or Poultry House.*

This may be assigned as a group practicum as suggested in Farmers' Bulletin 638, Exercise 18, Constructing an Individual Hog House, or it may be assigned as an individual home practicum.

LESSON 9.—*Other Buildings.*

1. Implement shed, tool house, shop.
2. Silos.
3. Miscellaneous.

Special references.—The following Farmers' Bulletins: 475, Ice Houses; 589, Homemade Silos.

LESSON 10.—*Farm Fences.*

1. Types of fences.
2. Fence building.
3. Gates.

Special references.—The following Farmers' Bulletins: 239, Corrosion of Fence Wire; 403, The Construction of Concrete Fence Posts.

EXERCISE 6.—*Building a Wire Fence.*

See Farmers' Bulletin 638, Exercise 31, Building a Wire Fence.

## FARM SANITATION.

(3 lessons.)

Reference.—Water Supply, Plumbing, and Sewage Disposal for Rural Homes, Department Bulletin No. 57.

LESSON 1.—*Sanitation and Farm Plans.*

1. Importance of sanitation.
2. Relation of sanitation to drainage.
3. Relation of farmhouses to buildings where animals are kept.
4. Relation of mosquitoes and other insects to health.

Illustrative material.—Illustrated lecture on Flies in Relation to Rural Sanitation: States Relations Service. Charts showing relation of flies and mosquitoes to health and other phases of sanitation.

LESSON 2.—*The Water Supply of the Farm.*

1. Importance of pure water.
2. Securing pure water.
3. Water under pressure in buildings.

Illustrative material.—Illustrated lecture on Farm Water Supplies: States Relations Service.

Special references.—The following Farmers' Bulletins: 73, Pure Water on the Farm; 262, Water for Table Use; 296, Wells and a Pure Water Supply; 309, Ice for Household Use. Clean Water and How to Get It on the Farm, Yearbook 1915.

LESSON 3.—*Sewage Disposal.*

1. Importance of proper disposal.
2. Sewage systems and house equipment.
3. Outhouses.

Special references.—The following Farmers' Bulletins: 463, The Sanitary Privy; 527, Sewage Disposal for Rural Homes. Sewage Disposal on the Farm, Yearbook 1916.

### AGRICULTURAL SURVEYING.

(3 lessons, 6 exercises.)

Lesson 1.—*Fundamentals of Land Measurement.*

1. Units of measurements.
2. Use and care of instruments.

Lesson 2.—*Field Methods.*

1. Making chain survey.
2. Leveling.

Lesson 3.—*Computing and Map Making.*

1. Making maps.
2. Computing area.

Exercise 1.—*Care and Use of Chains and Tapes.*

See Agricultural Engineering, by Davidson, Chapter I.

Exercise 2.—*Making a Chain Survey.*

See above reference, Chapter II.

Exercise 3.—*Making a Map.*

See above reference, Chapter III.

Exercise 4.—*Making and Adjusting a Level.*

See above reference, Chapter VII.

Exercise 5.—*Use of Homemade Level.*

See above reference, Chapter VIII.

Exercise 6.—*Use of Surveyor's Level.*

See Farmers' Bulletin 63, Exercise 33, Operation of a Level.

### FARM DRAINAGE.

(4 lessons, 2 exercises.)

References.—The following department bulletins: 71, The Wet Lands of Southern Louisiana and Their Drainage; 190, The Drainage of Irrigated Lands; 300, Excavating Machinery Used in Land Drainage; 304, Land Drainage by Means of Pumps. The Economy of Farm Drainage, Yearbook 1915. The following Farmers' Bulletins: 524, Tile Drainage on the Farm; 698, Trenching Machinery Used for the Construction of Trenches for Tile Drains.

Lesson 1.—*Importance of Drainage.*

1. Why drainage is necessary.
2. Relation of cost to increased value of land.
3. Lands needing drainage and lands which can be drained.
4. Kinds of drains.

Lesson 2.—*Tile Drainage.*

1. Superiority over other forms.
2. Kinds of tile.
3. Essentials of success in tile drains.
4. Capacity of tile drains.

Lesson 3.—*Laying Out the Drainage System.*

1. Systems of tile drainage.
2. Establishing grades and making maps.

Exercise 1.—*Mapping a Drainage System.*

See Farmers' Bulletin 638, Exercise 34, Tile-ditch Profits, and Exercise 35, Setting Up a Gauge Line.

LESSON 4.—*Construction of Tile Drains.*

1. Ditching methods.
2. Laying the tile.

EXERCISE 2.—*Laying Tile.*

See Farmers' Bulletin 638, Exercise 36, Digging Ditch and Laying Tile.

### IRRIGATION.

(2 lessons, 1 exercise.)

References.—Irrigation in Humid Climate, Farmers' Bulletin 46. Possibilities and Need of Supplemental Irrigation in the Humid Regions, Yearbook Separate 570.

LESSON 1.—*Relation of Irrigation to Agriculture.*

1. History of irrigation.
2. Present status of irrigation farming.
3. Supplemental irrigation in humid regions.

LESSON 2.—*Practical Irrigation.*

1. Laying out the ditches.
2. Use of water in irrigation.

Special references.—The following Farmers' Bulletins: 138, Irrigation in Field and Garden; 158, How to Build Small Irrigation Ditches; 263, Practical Information for Beginners in Irrigation.

EXERCISE.—*Preparing Garden for Irrigation.*

See Farmers' Bulletin 638, Exercises 38, 39, and 40, Irrigation.

### TERRACING.

(2 lessons, 1 exercise.)

Reference.—The Mangum Terrace in Its Relation to Efficient Farm Management, Bureau of Plant Industry Circular 94.

LESSON 1.—*Purposes of Terracing.*

1. Gullying and other forms of erosion.
2. Contours and terraces in ornamental planting and orchards.
3. Types of terraces.

LESSON 2.—*Construction of Terraces.*

1. Laying out contour lines.
2. Use of the A frame and other forms of levels.
3. Making the terrace.

EXERCISE.—*Construction and Use of Terrace Level.*

See Farmers' Bulletin 638, Exercise 37, Laying Out and Building a Terrace.

### ROADS.

(3 lessons, 2 exercises.)

References.—The following Farmers' Bulletins: 311, Sand-clay and Burnt-clay Roads; 321, The Use of the Split-log Drag on Earth Roads; 338, Macadam Roads; 505, Benefits of Improved Roads; 597, The Road Drag and How It Is Used.

LESSON 1.—*Importance of Good Roads.*

1. Relation of farming to roads.
2. Financial benefit.
3. Social benefits.

Lesson 2.—*Earth Roads.*

1. Construction of earth roads.
2. Maintenance of earth roads.
3. Use of drag.

Lesson 3.—*Improved Roads.*

1. Use of gravel.
2. Sand clay and burnt clay.
3. Macadam roads.
4. Top soiling.

Exercise 1.—*Survey of District Roads and Their Need of Improvement.*

An effort should be made to arouse and maintain community interest in good roads. The students should aid the teacher in making a road survey of the district and in working out a map showing the condition of the roads and bridges.

Exercise 2.—*Making and Use of a Drag.*

See Farmers' Bulletin 638, Exercises 41 and 42, Roads.

### ROPE WORK.

(1 lesson, 2 exercises.)

Lesson 1.—*Knots and Splices.*

1. Material.
2. Operations.

Exercises 1 and 2.—*Rope Work. Knots and Splices.*

See Farmers' Bulletin 638, Exercises 1, 2, and 3, Rope Work.

## SUGGESTIONS FOR PRACTICAL WORK IN RURAL ENGINEERING.

### CORRELATIONS.

1. The practical work should be correlated with the work in Mechanic Arts if such a course is given.

2. If a special course in mechanical drawing is not given, it will be well to give a number of lessons in the subject as preparation for the planning of farm buildings and the making of maps.

3. Much of the work may be correlated with mathematics and physics.

### EQUIPMENT.

A well-equipped shop, either in connection with the school farm or the work in mechanic arts, will be very useful. Likewise, the equipment of the farm in implements and machinery will be used to good advantage. Where no special equipment is provided, the class should take advantage of the farms of the students, near-by farms, and implement houses. It will be especially important to take advantage of such operation as construction of roads and buildings, thrashing, drainage, or any work connected with the course which may be going on in the vicinity of the school.

### COMMUNITY WORK.

Surveys of the community with regard to its use and care of machinery, its sanitary conditions and needs, its roads, water supply, drainage, and irrigation needs, will be of great benefit to the teacher and the class as well as to the community.

### PROJECTS.

Wherever it is possible to carry on any extensive practice in connection with the course, either by the class as a whole or by individual students, extra credit should be given for the work. Any of the lines of work suggested below may be either group projects carried on by the class or a number of the students at the school, or upon neighboring farms or individual projects conducted upon the home farm:

Construction of farm buildings.
Construction of walks, feeding floors, etc., of concrete.
Installation of heating, lighting, plumbing, and sewer systems.
Clearing and leveling land.
Laying out irrigation and drainage system.
Terracing.
Road making.
Installing engine and connecting with farm machinery.

### TEXTS AND REFERENCES FOR RURAL ENGINEERING.[1]

Benton, M. G. Shop Projects Based on Community Problems. Muncie, Ind.: Vocational Supply Co., 1915.

Blackburn, S. A. Problems in Farm Woodwork. Peoria, Ill.: The Manual Arts Press, 1915.

Bryce, J. M., and Mayne, D. D. Farm Shopwork. New York: The American Book Co., 1915.

Campbell, H. C. Concrete on the Farm and in the Shop. New York: The Norman W. Henley Co., 1916.

Clarkson, R. P. Practical Talks on Farm Engineering. New York: Doubleday, Page & Co., 1915.

Davidson, J. B. Agricultural Engineering. St. Paul, Minn.: Webb Publishing Co., 1913.

Davidson, J. B., and Chase, L. W. Farm Machinery and Farm Motors. New York: Orange Judd Co., 1908.

Exblaw, K. J. T. Farm Structures. New York: The Macmillan Co., 1914.

French, T. E., and Ives, F. W. Agricultural Drawing and the Design of Farm Structures. New York: The McGraw Hill Book Co., 1915.

Fuller, M. L. Domestic Water Supply for the Farm. New York: John Wiley & Sons Co., 1912.

Koester, Frank. Electricity for the Farm and Home. New York: Sturgis & Walton Co., 1913.

Roehl, L. M. Agricultural Woodworking. Milwaukee, Wis.: The Bruce Publishing Co., 1916.

Verrill, A. H. Knots, Splices, and Rope Work. New York: The Norman W. Henley Co., 1916.

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[1] These books are recommended by the Commission on Accredited Schools of the Southern States.

## OUTLINE FOR RURAL ECONOMICS AND FARM MANAGEMENT—FOURTH YEAR.

(One-half unit, 52 lessons, 36 exercises.)

General references.—A Method of Analyzing the Farm Business, Farmers' Bulletin 661. The following bulletins of the Bureau of Plant Industry: 236, Farm Management; 259, What is Farm Management? Some Outstanding Factors in Profitable Farming. A Graphic Summary of American Agriculture, Yearbook 1915.

LESSON 1.—*Introduction.*

1. Definitions.
2. Relations of agriculture to other industries.

LESSON 2.—*Historical Sketch.*

1. The beginnings of agriculture.
2. Development of modern agriculture.

LESSON 3.—*Farming as a Means of Making a Living.*

1. Comparison with other occupations.
2. Opportunities in agriculture.

LESSON 4.—*Farming as a Mode of Life.*

1. Living in the country.
2. The farm as a home.

LESSON 5.—*Problems of Rural Social Life.*

1. Country life *v.* city life.
2. Factors for social betterment.
3. Personal obligations.

Special references.—Articles in the following Yearbooks: 1914, Organization of a Rural Community; 1915, How the Department of Agriculture Promotes Organization in Rural Life.

LESSON 6.—*City-bred v. Country-bred Farmers.*

1. Advantages of country training.
2. Advantages of city training.
3. The back-to-the-land movement.

Special reference.—Movement of City and Town to Farms, Yearbook 1914.

LESSON 7.—*Farming as a Business.*

1. Comparison with other business.
2. Business principles to be applied.

EXERCISE 1.—*A Suggested Debate.*

Time equal to one laboratory period (a double period) may be spent profitably in a debate involving the question of the relative opportunities for young men in the country and in the city. It will be best to apply the question to the opportunities in the district where the school is located as compared with a neighboring town with which the students are familiar.

LESSON 8.—*The Distribution of Wealth.*

1. Economic principles involved.
2. Relation to use of land.
3. Relation to labor.

LESSON 9.—*Capital.*

1. Relation to type of farming.
2. Farming with small capital.

LESSON 10.—*Rural Credits.*

1. The farmer and the banker.
2. Necessity of good credit.
3. Farm credit systems.
4. The amortization plan.

EXERCISE 2.—*A Suggested Debate.*

Another debate may be introduced at this time to arouse interest in the Federal farm loan act and its application to local conditions. Such a question as "Resolved: That this community (the school district) should organize a local farm-loan association," may fit certain conditions and furnish an excellent means of getting the students to make a survey of local conditions as well as to get a better idea of what the Federal Government has done for the farmer.

Reference material, in addition to that given, may be secured from the Federal Farm Loan Board, Washington, D.C.

Special references.—The following Farmers' Bulletins: 593, How to Use Farm Credit; 654, How Farmers May Improve Their Personal Credit; 792, How the Federal Farm Loan Act Benefits the Farmer.

LESSON 11.—*Land Tenure.*

1. Ownership *v.* rental.
2. Methods of rental.
3. The problem of tenant farming.

Special references.—The following Farmers' Bulletins: 280, A Profitable Tenant Dairy Farm; 437, A System of Tenant Farming and Its Results. The following Department Bulletins: 337, A Study of the Tenant Systems of Farming in the Yazoo and Mississippi Delta; 411, Systems of Renting Truck Farms in Southwestern New Jersey. Causes Affecting Farm Values, Yearbook 1905.

LESSON 12.—*Acquiring Land.*

1. American *v.* European systems.
2. Opportunities for young men.
3. Methods of acquiring land.

LESSON 13.—*Systems of Operation.*

1. Syndicate farming *v.* private ownership.
2. Maintaining fertility *v.* spoliation.

LESSON 14.—*Types of Farming.*

1. Factors which determine type.
2. A comparison of types.

Special reference.—Types of Farming, Yearbook 1908.

LESSON 15.—*General v. Special Farms.*

1. Advantages and disadvantages of general farming.
2. Advantages and disadvantages of special farming.
3. Factors which determine a choice.
4. Present need for diversification in the South.

Special reference.—Diversified Farming Under Plantation System, Farmers' Bulletin 299.

### Lesson 16.—*Extensive v. Intensive Farming.*

1. Advantages and disadvantages of extensive farming.
2. Advantages and disadvantages of intensive farming.
3. Factors which determine a choice.

Special references.—Articles in the following Yearbooks: 1902, Systems of Farm Management in the United States; 1905, Diversified Farming in the Cotton Belt; 1908, Causes of Southern Rural Conditions and Small Farm as Important Remedy. The following Farmers' Bulletins: 472, Systems of Farming in Central New Jersey; 519, Example of Intensive Farming in the Cotton Belt.

### Lesson 17.—*A Study of Successful Farms—Local.*

1. The farm and what has been accomplished.
2. Factors which have meant success.
3. A local survey.

### Exercises 3–6.—*Local Farm Surveys.*

Time equal to four double periods should be spent by the students in making an analysis of the home farm business under the direction of the teacher. Directions for this work and suitable forms will be found in Farmers' Bulletin 661, An Analysis of the Farm Business. The teacher may use some of the students in helping him make a general survey of the farms of the community. The results of such a survey will prove invaluable in adapting this course to the needs of the community.

### Lesson 18.—*A Study of Successful Farms—General.*

1. The farm and what has been accomplished.
2. Factors which have meant success.
3. General farm surveys.

Special references.—A Model Farm, Yearbook 1903. A Successful Dairy Farm, Bureau of Plant Industry Bulletin 102, part 2. The following Farmers' Bulletins: 242, An Example of Model Farming; 272, A Successful Hog and Seed-corn Farm; 280, A Profitable Tenant Dairy Farm; 310, A Successful Alabama Diversification Farm; 312, A Successful Southern Hay Farm; 355, A Successful Poultry and Dairy Farm; 264, A Profitable Cotton Farm. The following Department Bulletins: 32, An Example of Successful Farm Management in Southern New York; 41, A Farm-management Survey of Three Representative Areas in Indiana, Illinois, and Iowa; 341, Farm-management Practice of Chester County, Pa.; 492, An Economic Study of Farming in Sumter County, Ga.

Problems.—It will be profitable to have the students work out problems in connection with many of the lessons to follow. Those given in Farm Management, by Boss, should be suggestive of others having local application.

### Lesson 19.—*Farm Equipment.*

1. Relation of machinery to size of farm and type of farming.
2. First costs and depreciation.
3. Maintenance of equipment.

Special references.—Minor Articles of Farm Equipment, Bureau of Plant Industry Circular 44. A Study of Farm Equipment in Ohio, Bureau of Plant Industry Bulletin 212.

Lesson 20.—*Buying Farm Equipment.*

1. Local dealers *v.* mail-order houses.
2. Cash payment *v.* credit.
3. Cooperation in buying.

Lesson 21.—*Increasing Production.*

1. Relation of acre yield to profit.
2. Relation of production to prices.
3. Factors in crop increase.

Lesson 22.—*Maintenance of Fertility.*

1. Obligations to coming generation.
2. Ways of increasing productivity.
3. Relation to farm management.
4. Restoring lost fertility.
5. Preventing erosion.

Special references.—The Mangum Terrace in Its Relation to Efficient Farm Management, Bureau of Plant Industry Circular 94. Also, the following Farmers' Bulletins: 257, Soil Fertility; 326, Building up a Run-down Cotton Plantation.

Lesson 23.—*Live Stock and Soil Fertility.*

1. Animal products *v.* plant products in relation to plant food.
2. Value of barnyard manure.
3. Care and use of barnyard manure.

Special references.—The Function of Live Stock in Agriculture, Yearbook 1916. The following Farmers' Bulletins: 192, Barnyard Manure; 614, A Corn-belt Farming System Which Saves Harvest Labor by Hogging Down Crops; 704, Grain Farming in the Corn Belt with Live Stock as a Side Line.

Lesson 24.—*Economics of Animal Production.*

1. Live stock as a means of marketing low-priced crops.
2. Live stock and cheap labor.
3. Relation of live stock to type of farming and size of farm.

Special reference.—Cropping Systems for Stock Farms, Yearbook 1907.

Lesson 25.—*Some Live-Stock Problems.*

1. Pure-bred *v.* grade stock.
2. Breeding animals *v.* market stock.
3. Depreciation and increase in value of stock.

Special references.—The following department Bulletins: 49, The Cost of Raising a Dairy Cow; 413, Influence of Age on the Value of Dairy Cows and Farm Work Horses.

Lesson 26.—*Rotation of Crops.*

1. Benefits of crop rotation.
2. Essentials of a good system.

Lesson 27.—*Rotation of Crops*—Continued.

1. Classification of crops.
2. General rotations.

Lesson 28.—*Rotation of Crops*—Continued.

1. Rotations for the cotton belt.
2. Rotations for special farms.

Special references.—Suggested Cropping System for the Black Lands of Texas, Bureau of Plant Industry Circular 84. Planning Cropping Systems, Bureau of

Plant Industry Bulletin 102, Part 3. Articles in the following Yearbooks: 1905, Diversified Farming in the Cotton Belt; 1907, Cropping Systems for Stock Farms; 1911, Rotations in the Corn Belt. Diversified Farming under the Plantation System, Farmers' Bulletin 299.

LESSON 29.—*Planning the Farm and Farmstead.*

1. Need of careful planning.
2. Size of farms.
3. Eliminating waste land.

Special reference.—Waste Land and Wasted Land on Farms, Farmers' Bulletin 745.

LESSON 30.—*Planning the Farm and Farmstead*—Continued.

1. Size and shape of fields.
2. Relation of field to farmstead.

LESSON 31.—*Planning the Farm and Farmstead*—Continued.

1. Relation of farms to highways.
2. Laying out the farm.

Special reference.—A Model Farm, Yearbook, 1903.

LESSON 32.—*Planning the Farm and Farmstead*—Continued.

1. The farm house.
2. Other farm buildings.
3. Arrangement of buildings.

EXERCISES 7–10.—*Drafting Farm Plans.*

Four double periods should be spent in drafting and in a critical examination of farm plans by the students. Such plans should include the home farms of the students and ideal plans of such types of farms as the individual students have a special interest in. The plans should be drawn to scale and traced with ink. Such a grade of work should be required that the students will desire to keep the plans.

LESSON 33.—*Replanning Problems.*

1. A study of replanned farms.

LESSON 34.—*Replanning Problems*—Continued.

1. Replanning the farmstead.
2. Remodeling of buildings.

LESSON 35.—*Replanning Problems*—Continued.

1. Rearrangement of local farms.
2. Rearrangement of local farmsteads.

EXERCISES 11–14.—*Replanning Problems.*

After the students have had general practice in making farm plans four double periods may be spent profitably in replanning farms and farmsteads of the community.

Special reference.—Replanning a Farm for Profit, Farmers' Bulletin 370.

LESSON 36.—*Farm Labor.*

1. Why there is a labor problem.
2. Kinds of farm labor.
3. The tenant problems.

LESSON 37.—*Management of Farm Labor.*

1. A day's work for one man.
2. Efficiency in management.
3. Seasonal distribution.

Special references.—The following department bulletins: 3, Normal Day's Work for Various Farm Operations; 412, The Normal Day's Work of Farm Implements, Workmen, and Crews in Western New York. Articles in the following Yearbooks: 1910, Supply and Wages of Farm Labor; 1911, Seasonal Distribution of Labor on the Farm.

EXERCISES 15 AND 16.—*Planning Work Schedules.*

After the work with farm plans two double periods should be taken in planning work schedules for the home farms of the students and other farms which they have planned and in which they have an interest.

LESSON 38.—*Factors of Agricultural Production.*

1. Land.
2. Capital goods.
3. Population.

LESSON 39.—*Cost of Production.*

1. Necessity of knowing costs.
2. Factors which determine cost.
3. Interest on permanent investment and depreciation.

EXERCISES 17–20.—*Cost of Production.*

Time equal to four double periods should be spent in working out costs of production on local farms. Records kept in connection with home projects and club work may form the basis of this work.

Special reference.—Farm Records and Accounts—Suggestions for Teaching the Subject in Secondary Schools, States Relations Service Document 38.

LESSON 40.—*Cost of Production*—Continued.

1. Cost of man labor and horse labor.
2. Cost of live-stock production.
3. Contribution of farm to farmer's living.
4. Wastes of the farm.

Special references.—The following Farmers' Bulletins: 635, What the Farm Contributes Directly to the Farmer's Living; 746, The Farmer's Income. The following bulletins of the Bureau of Statistics, United States Department of Agriculture: 16, Cost of Cotton Production; 48, Cost of Producing Minnesota Farm Products; 73, Cost of Producing Farm Products; 88, Cost of Producing Minnesota Dairy Products. The following Department Bulletins: 29, Crew Work Costs and Returns in Commercial Orcharding in West Virginia; 49, The Cost of Raising a Dairy Cow; 130, Operating Cost of a Well-established New York Apple Orchard; 321, Cost of Fencing Farms in North Central States; 338, Machinery Cost of Farm Operations in Western New York; 410, Value to Farm Families of Food, Fuel, and Use of Home; 446, Cost of Producing Apples in Wenatchee Valley, Wash.

EXERCISES 21–26.—*Farm Bookkeeping.*

In connection with the general lessons in farm accounts time equal to six double periods should be given to practice in the application of the general principles of bookkeeping to farm accounts. Stress should be placed upon forming habits of neatness and accuracy.

LESSON 41.—*Farm Records and Accounts.*

1. Necessity of farm records and accounts.
2. Essentials of a farm-account system.

Special references.—The following Farmers' Bulletins: 511, Farm Bookkeeping; 572, A System of Farm Cost Accounting; 661, An Analysis of the Farm Business; 782, The Use of a Dairy for Farm Accounts.

LESSON 42.—*Farm Records and Accounts*—Continued.

1. Kinds of accounts.
2. Personal accounts.

EXERCISES 27–32.—*Home Farm Records.*

Time equal to six double periods should be spent in applying the principles of farm bookkeeping to home records and accounts. The needs brought out in an analysis of the farm business should form a basis for this work.

LESSON 43.—*Farm Records and Accounts*—Continued.

1. General accounts.
2. The farm inventory.

EXERCISES 33 AND 34.—*Farm Inventories.*

In connection with the farm accounting two double periods should be spent in taking inventories on the home farm or representative farms in the school district.

LESSON 44.—*Farm Records and Accounts*—Continued.

1. Receipts and expenses.
2. Miscellaneous accounts.

LESSON 45.—*Farm Records and Accounts*—Continued.

1. Field accounts.
2. Labor accounts.

LESSON 46.—*Farm Records and Accounts*—Continued.

1. Animal-husbandry accounts.
2. Animal-husbandry records.
3. Animal-breeding records.

LESSON 47.—*Marketing Farm Products.*

1. Selling at harvest time.
2. Storing for higher prices.

Special references.—The following Farmers' Bulletins: 764, Cotton Ginning Information for Farmers; 775, Losses From Selling Cotton in the Seed. Disadvantages of Selling Cotton in the Seed, department bulletin 375.

LESSON 48.—*Marketing Farm Products*—Continued.

1. Wholesale *v.* retail.
2. Selling on commission.
3. Advertising.
4. Using the parcel post.

Special references.—The following department bulletins: 266, Outlets and Methods of Sale for Shippers of Fruits and Vegetables; 267, Methods of Wholesale Distribution of Fruits and Vegetables on Large Markets; 315, Cantaloup Marketing in the Larger Cities, With Car-lot Supply, 1914; 331, The Handling and Shipping of Fresh Cherries and Prunes from the Willamette Valley. Articles in the following Yearbooks: 1904, Consumers' Fancies; 1911, Handling and Marketing Eggs; 1912, Improved Methods of Handling and Marketing Cotton. Economics of Crop Disposal, Bureau of Plant Industry Bulletin 118. The following Farmers' Bulletins: 62, Marketing Farm Produce; 703, Suggestions for Parcel-post Marketing.

LESSON 49.—*Cooperation in Agriculture.*

1. Need of cooperation.
2. Methods of cooperation.
3. What has been accomplished.

Special references.—Cooperative Organization Business Methods. Department bulletin 178. Articles in the following Yearbooks: 1910, Cooperation in Handling and Marketing Fruits; 1913, Organization of Rural Interests; 1914, Cooperative Marketing and Financing of Marketing Associations; 1914, How the Department of Agriculture Promotes Organization in Rural Life; 1915, The Cooperative Purchase of Farm Supplies. Cooperative Live-stock Shipping Associations, Farmers' Bulletin 718.

LESSON 50.—*Choosing a Region.*

1. Consideration of climate, soil, etc.
2. Type of farming.

Special reference.—Opportunities in Agriculture, Yearbook 1904

LESSON 51.—*Choosing a Farm.*

1. Importance of careful consideration.
2. Characteristics of community.

LESSON 52.—*Choosing a Farm*—Continued.

1. Characteristics of the farm.
2. Fitting a farm to personal ideals and circumstances.

EXERCISES 35 AND 36.—*Scoring Farms.*

Two double periods should be spent in scoring farms in the community and determining their value. Preference should be given farms for sale.

Special references.—How to Choose a Farm, by Hunt, and Farm Management, by Boss, have suggestive score cards.

## HOME PROJECTS IN RURAL ECONOMICS AND FARM MANAGEMENT.

No definite time and credit for home projects is suggested for this course, as a half year is a limited time in which to cover the subject, and the home work in farm management is such that time and credit must be adjusted to fit individual students. Effort should be made, however, to link practical work in farm management at home with the work of the school and to encourage such work by giving extra credit.

Work in connection with the keeping of farm records and accounts and the making of community surveys may be made extensive enough to consider a project which would be worthy of extra credit. Wherever students have the general management of a farm or any extensive phase of the farm work, an effort should be made to connect this work in such a way with the course in farm management that it will be worthy of school credit. Such work should offer an excellent opportunity to apply the principles brought out in the classroom.

## TEXTS AND REFERENCES FOR RURAL ECONOMICS AND FARM MANAGEMENT.[1]

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Coulter, J. L. Cooperation Among Farmers. New York: Sturgis Walton Co., 1911.

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Nourse, E. G. Agricultural Economics. Chicago: University of Chicago Press, 1916.

Orwin, C. S. Farm Accounts. Cambridge, Mass.: University Press, 1914.

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Sanford, A. H. The Story of Agriculture in the United States. Boston: D. C. Heath & Co., 1916.

Steiner, H. L. How to Keep Farm Accounts. Toledo, Ohio: Author, 1912.

Taylor, H. C. An Introduction to the Study of Agricultural Economics. New York: The Macmillan Co., 1914.

Vye, J. A. Farm Accounts. St. Anthony Park, Minn.: Author, 1906.

Warren, G. F. Farm Management. New York: The Macmillan Co., 1913.

Warren, G. F., and Livermore, K. C. Laboratory Exercises in Farm Management. New York: The Macmillan Co., 1913.

Weld, L. D. H. The Marketing of Farm Products. New York: The Macmillan Co., 1916.

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[1] These books are recommended by the Commission on Accredited Schools of the Southern States.

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UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 593**

**Contribution from the States Relations Service**
**A. C. TRUE, Director.**

**Washington, D. C.** **PROFESSIONAL PAPER.** **December 20, 1917**

# JUDGING SHEEP AS A SUBJECT OF INSTRUCTION IN SECONDARY SCHOOLS.[1]

By H. P. BARROWS, *Specialist in Agricultural Education.*

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## INTRODUCTION.

Many rural districts of the United States are not awake to the opportunities connected with sheep husbandry. In sections where sheep form an important part of the farm live stock the possibilities of keeping the boy on the farm are increased by allowing him the care of a few sheep on his own account. Much can be done toward arousing an interest among the farmers of the community and an enthusiasm on the part of the young people by teaching the subject properly in the schools. Lessons on types and breeds of sheep furnish a suitable introduction to a study of wool and mutton production. If, in these lessons, an abundance of illustrative material is used, and they are accompanied by practice in judging, interest will be aroused in the lessons to follow. Students who may have little interest in ordinary sheep often become enthusiastic when made acquainted with the results and possibilities of good breeding. Although it will not be possible in the time available in a secondary course to train expert judges, a good start may be made if the work is directed right. The instructor should aim to fix proper ideals in the minds of the students, to develop their powers of observation, and to arouse such interest that the students will continue the work of their own accord.

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[1] Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education, with the aid of the Bureau of Animal Industry.

NOTE.—This bulletin is intended for the use of teachers of secondary agriculture.

## CLASSROOM INSTRUCTION.

*Use of illustrative material.*—Before students begin practice in judging an effort should be made to fix in their minds an ideal of the type (fig. 1) or breed which is being considered. Nothing else in this work has value equal to living specimens which approach perfection. The teacher should make a survey of the farms surrounding his school to learn where the best animals are kept. In visiting these farms the class may study methods of breeding and management as well as breeds. In some cases it may be most convenient to have the animals brought to the school. It will not be possible to study living specimens of all the breeds, neither will it always be convenient to have lessons with the animals present. Fortunately there are many pictures of prize-winning sheep which the teacher may use. If files are not kept of the leading live-stock journals, clippings should be made of all good pictures and these prints mounted upon cards for classroom use. Such pictures as those shown

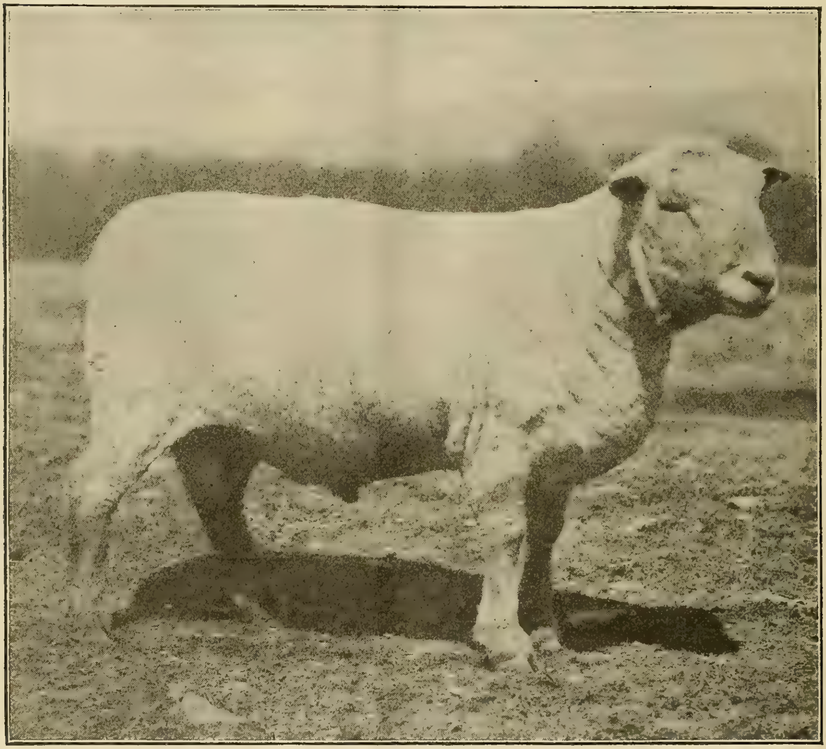

FIG. 1.—A good mutton type.

in figures 2, 3, and 4 may be enlarged as charts[1] or copied upon the blackboard. A projection lantern with an opaque attachment will enable the teacher to project mounted pictures as well as lantern slides upon the screen. A good set of lantern slides is almost indispensable in connection with any study of types and breeds of live stock.[2]

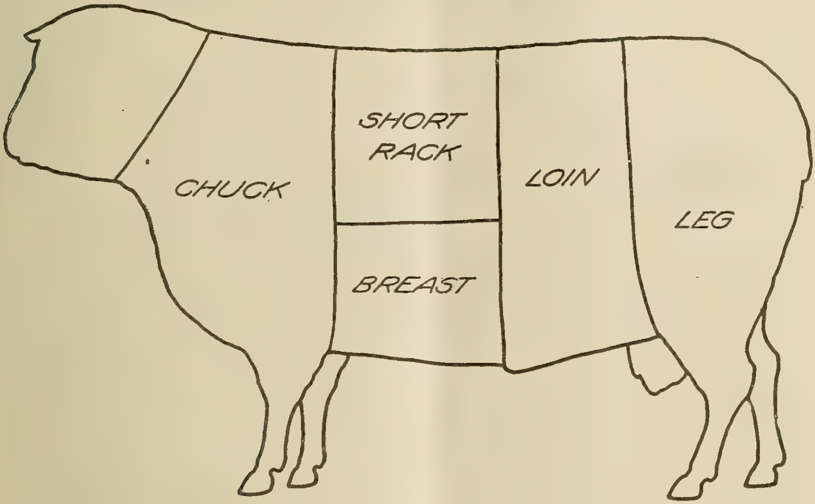

FIG. 2.—Chart for teaching cuts of mutton.

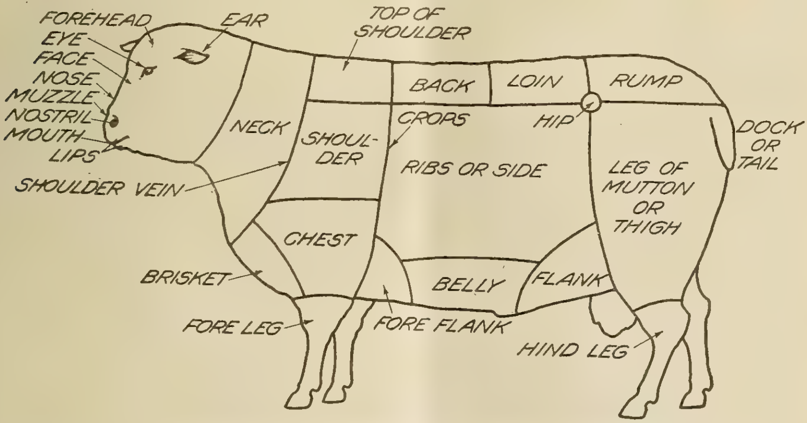

FIG. 3.—Chart for teaching names of parts of a sheep.

Wherever any extensive study is made of wool, a permanent exhibit showing classes and grades of wool will be found very helpful.

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[1] Good charts of such pictures may be obtained by tracing the outlines upon ordinary tracing cloth, mounting upon glass as a lantern slide, projecting with the stereopticon, and tracing upon cloth or paper. Light-colored window shades are suitable for this purpose.

[2] Lantern slides illustrating types and breeds of sheep may be obtained from the Division of Agricultural Instruction of the States Relations Service. A list of these and other slides will be mailed upon request.

*A study of types and breeds.*[1]—Practice in judging should be accompanied by a study of the types and breeds of sheep which are important in the United States. Emphasis should be placed upon type and breeds of local importance. There are a great many classifications for the breeds of sheep, but the breeds common in America may be conveniently grouped on a basis of the kind of wool they produce, as follows (figs. 5, 6, and 7):

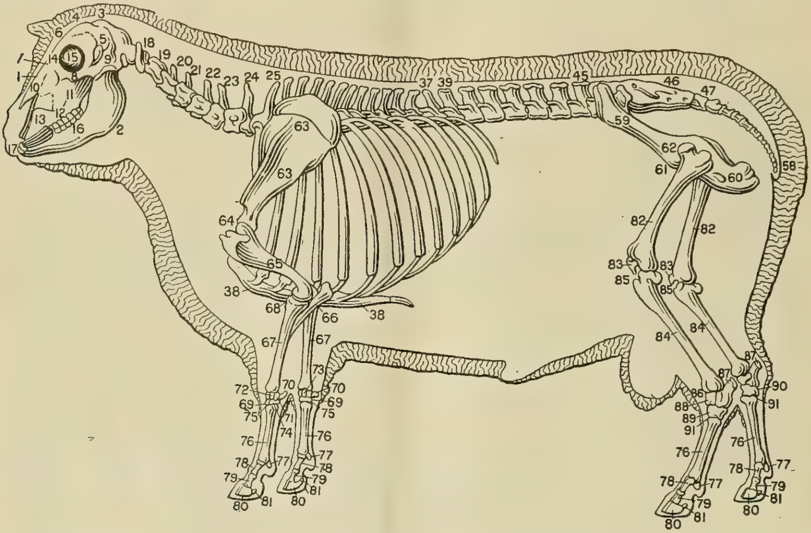

FIG. 4.—Chart for teaching relation of body outline to skeleton parts: 1, upper jaw; 2, lower jaw; 3, parietal; 4, frontal ridge; 5, horn cores; 6, frontal; 7, lachrymal; 8, malar; 9, temporal; 10, nasal; 11, maxillary; 12, upper molars; 13, premaxillary; 14, frontal spine; 15, eye socket; 16, lower molars; 17, incisors; 18–24, cervical vertebrae; 18, atlas; 19, axis; 25–37, dorsal vertebrae; 38, sternum; 39–45, lumbar vertebrae; 46, sacrum; 47–58, caudal vertebrae; 59, ilium; 60, ischium; 61, pubis; 62, hip joint; 63, scapula; 64, shoulder joint; 65, humerus; 66, ulna; 67, radius; 68, elbow joint; 69–75, carpal bones; 76, metacarpal; 77, sesamoid; 78, pastern; 79, coronary; 80, coffin bones; 81, sesamoid; 82, femur; 83, patella; 84, tibia; 85, knee joint; 86, hock joint; 87–91, tarsal bones.

### CLASSIFICATION OF THE BREEDS OF SHEEP.

Fine wool:
- American Merino.
- Delaine Merino.
- Rambouillet.

Medium (or middle) wool:
- Southdown.
- Shropshire.
- Hampshire.
- Oxford.
- Dorset Horn
- Suffolk.
- Cheviot.

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[1] Farmers' Bulletin 576, Breeds of Sheep for the Farm, should be used in connection with this study.

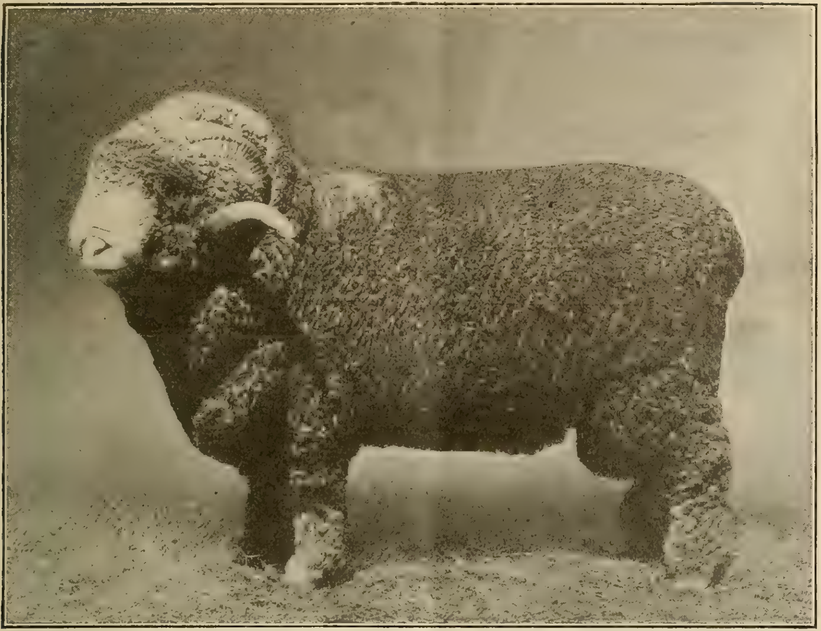

FIG. 5.—A fine wool sheep—Rambouillet.

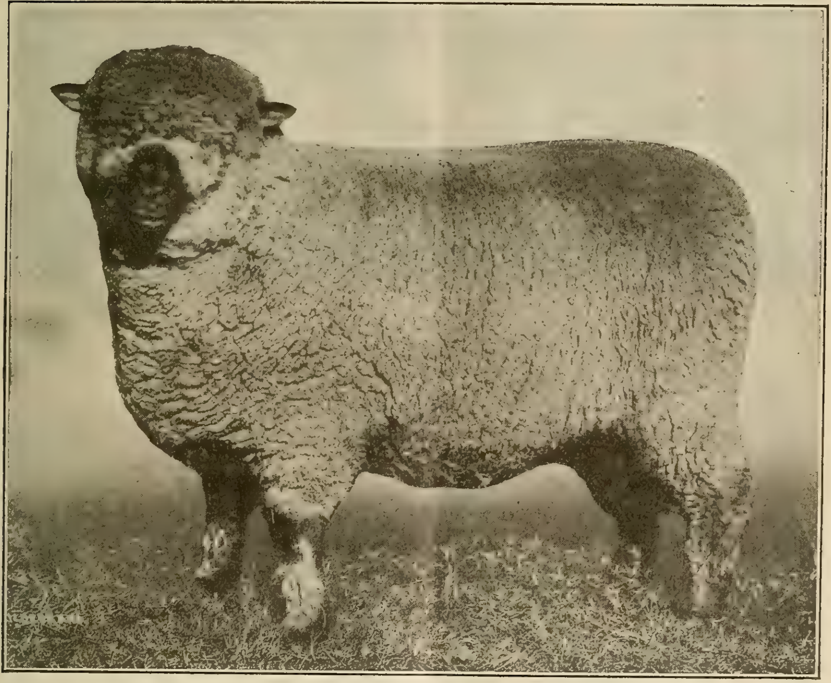

FIG. 6.—A medium wool sheep—Shropshire.

Coarse (or long) wool:
- Cotswold.
- Lincoln.
- Leicester.
- Kent, or Romney Marsh.

The first group sometimes is classed as "wool" sheep and the other two groups as "mutton" sheep.

Although the students should learn to recognize most of the breeds named above, a detailed study, with practice in judging, should be made of but one or two of the important breeds in the school district.

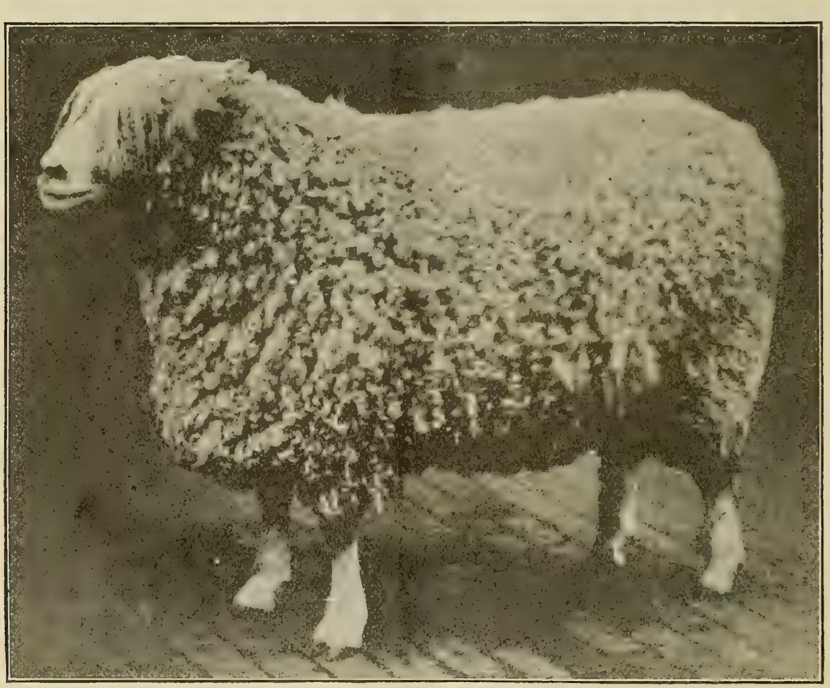

FIG. 7.—A long wool sheep—Cotswold.

In sections where one class of sheep is raised almost exclusively, comparatively little time should be given the other classes.

*Market classes and grades.*—In teaching stock judging, confining the study to pure-bred animals may furnish a good foundation for the training of a show-ring judge but will not give the training needed by many farmers. In the Corn Belt and other territory adjacent to large markets, where feeder sheep are purchased and fattened, it is especially important for the farmer to know the classifications and demands of the market buyers. If the sheep business of the school district is confined largely to the fattening of sheep purchased, instead of sheep reared on the home farm, then a consideration of market grades and classes should be given first place. In connection with this study a visit to a packing house and its stockyards may be made very profitable if it can be arranged. At such a place there is usually an opportunity to study the methods used in handling the sheep as they arrive, as well as their conversion into mutton ready for the dealer.

If it is not convenient to visit a packing house it may be possible to visit a local meat dealer and there make a study of wholesale and retail cuts of mutton or to visit a farm where sheep and swine are killed for meat. It will be profitable to compare the hog carcass with the mutton carcass to note the difference in the depth of fat covering the body skeleton. Even the comparison of a pork chop with a mutton chop at the school will be worth while in illustrating such a fact.

The classification shown on page 8 is from University of Illinois Agricultural Experiment Station Bulletin 129, Market Classes and Grades of Sheep.

*Relation of type to efficiency.*—In connection with a visit to a packing house or a dealer to afford the students an opportunity to make a comparative study of sheep carcasses, the sheep should be considered in the classroom as a meat-producing machine and the relation of type to efficiency brought out. It is well to consider the sheep from the standpoint of the packer, as it is the buyer who ultimately will determine its value. Charts, such as figure 2, should be used to show the wholesale and retail cuts of meat, with relative prices marked off on an outline of a sheep. Quality of meat, smoothness in dressing, relative size, and age in connection with the season are factors considered by packers in determining the price to be paid per pound. In considering the sheep from the feeder's point of view, emphasis should be given such points as capacity for feed, efficiency in its use, strength, and vigor.

The sheep should be considered also as a wool-producing animal and the amount and quality of the wool given attention. Though a technical study of wool has not been considered generally a phase of agriculture, yet, now that the importance of wool production is increasing, the farmer engaged in the industry should know more about his product.

The class should give most emphasis to the sheep from the breeder's point of view. The breeder should pay attention to all the points important to the buyer and the feeder and at the same time consider such points as fecundity, strength of constitution, and prepotency. The last-named quality will involve a study of records and pedigrees of breeding animals. Such a study fits more logically with a study of breeding. In taking up sheep as a home project, every encouragement should be given students to get hold of registered animals of good breeding.

*Outline of market classes and grades of sheep.*

| Classes. | Subclasses. | Grades. |
|---|---|---|
| Mutton sheep. (Native and western sheep.) | Lambs. | Prime. |
| | | Choice. |
| | | Good. |
| | | Medium. |
| | | Common or culls. |
| | Yearlings. | Prime. |
| | | Choice. |
| | | Good. |
| | Wethers. | Prime. |
| | | Choice. |
| | | Good. |
| | | Common. |
| | Ewes. | Prime. |
| | | Choice. |
| | | Good. |
| | | Medium. |
| | | Common or culls. |
| | Bucks and stags. | Choice. |
| | | Good. |
| | | Common. |
| Feeder sheep. (Western sheep.) | Lambs. | Fancy selected. |
| | | Choice. |
| | | Good. |
| | | Medium. |
| | | Common. |
| | Yearlings. | Choice. |
| | | Good. |
| | | Common. |
| | Wethers. | Choice. |
| | | Good. |
| | | Medium. |
| | | Common. |
| | Ewes. | Choice. |
| | | Good. |
| | | Medium. |
| | | Common. |
| Breeding sheep. (Native and western sheep.) | Ewes. | Fancy selected. |
| | | Choice. |
| | Bucks. | Good. |
| | | Common. |
| | | (Not graded.) |

Miscellaneous:
- Hothouse lambs.
- Export sheep.
- Throw-outs.
- Dead sheep.
- Goats.

*The score card.*—Before the score card is taken up the teacher should be sure that every student knows the terms used in judging and the names of the parts of a sheep. A diagram of a sheep may be placed on the blackboard with the names of parts omitted and the students required to supply them. In considering the score card in the classroom, the students should understand that it is a brief detailed description of a perfect animal designed to aid them in establishing an ideal in their minds. There are two classes of score cards: (1) Those for classes or types, such as mutton sheep, fine-wool sheep, etc.; and (2) breed score cards, which usually are supplied as standards of perfection by the various breed associations. It should be borne in mind that all score cards are arbitrary in their assignment of values. As there will always be a difference of opinion upon relative values of points and upon forms of grouping, variation in score cards is likely to continue. A use of the score card should aid the students in making a systematic examination of the animal, giving attention to details, and should give them a sense of relative values in judging. Many of the State colleges and departments of agriculture furnish cards for use in school work. The following score card is from the Agricultural Experiment Station of Purdue University:

*Score card.*

MUTTON SHEEP—FAT.

| Scale of points. | Standard. | Student's score. | Corrected score. |
|---|---|---|---|
| 1. *Age* | | | |
| *General appearance*—38 per cent: | | | |
| 2. *Weight*, score according to age | 8 | | |
| 3. *Form*, long, level, deep, broad, low set, stylish | 10 | | |
| 4. *Quality*, clean bone; silky hair; fine, pink skin; light in offal, yielding high percentage of meat | 10 | | |
| 5. *Condition*, deep even covering of firm flesh, especially in regions of valuable cuts. Points indicating ripeness are thick dock, back thickly covered with flesh, thick neck, full purse, full flank, plump breast | 10 | | |
| *Head and neck*—7 per cent: | | | |
| 6. *Muzzle*, fine; mouth large; lips thin; nostrils large and open | 1 | | |
| 7. *Eyes*, large, clear, placid | 1 | | |
| 8. *Face*, short; features clean-cut | 1 | | |
| 9. *Forehead*, broad, full | 1 | | |
| 10. *Ears*, fine, alert | 1 | | |
| 11. *Neck*, thick, short, free from folds | 2 | | |
| *Forequarters*—7 per cent: | | | |
| 12. *Shoulders*, covered with flesh, compact on top, snug | 5 | | |
| 13. *Brisket*, neat, proportionate; breast wide | 1 | | |
| 14. *Legs*, straight, short, wide apart, strong; forearm full; shank smooth, fine | 1 | | |
| *Body*—20 per cent: | | | |
| 15. *Chest*, wide, deep, full | 4 | | |
| 16. *Ribs*, well sprung, long, close | 4 | | |
| 17. *Back*, broad, straight, long, thickly fleshed | 6 | | |
| 18. *Loin*, thick, broad, long | 6 | | |
| *Hindquarters*—16 per cent: | | | |
| 19. *Hips*, far apart, level, smooth | 2 | | |
| 20. *Rump*, long, level, wide to tail-head | 4 | | |
| 21. *Thighs*, full, deep, wide | 4 | | |
| 22. *Twist*, plump, deep | 5 | | |
| 23. *Legs*, straight, short, strong; shank fine, smooth | 1 | | |
| *Wool*—12 per cent: | | | |
| 24. *Quantity*, long, dense, even | 4 | | |
| 25. *Quality*, fine, pure; crimp close, regular, even | 4 | | |
| 26. Condition, bright, sound, clean, soft, light | 4 | | |
| Total | 100 | | |

## DESCRIPTION OF MUTTON SHEEP.

### GENERAL APPEARANCE.

*Weight.*—Weight always should be considered in connection with age in market sheep and with sex in breeding animals. Sheep 1 year old and under are considered lambs on the market. Lambs are desirable as butcher stock, because they are in greatest demand by the consumer and are most profitable to the producer if he is raising sheep only for mutton production. Weight is influenced by breed and degree of fatness as well as by age. Although plenty of weight is desired, there is objection to great weight because it is likely to be associated with coarseness and a low dressing percentage and give cuts too large to suit the demands of the retail trade. Lambs weighing from 70 to 80 pounds are in greatest demand. Mature wethers should weigh over 95 pounds.

*Form.*—The point of view of the butcher should be kept in mind in considering the form of a mutton steak. As the most valuable cuts of meat are on the hind quarters and loin, the butcher requires a heavy leg of mutton and a broad back with a deep, full loin. In order to secure this development in the hind quarters there must be a corresponding development in other parts of the body. The general form, then, should be smooth and even, a large frame without heavy bones giving a plump appearance. Low-set, broad forms generally have a special development of loin and leg and dress out with a relatively small percentage of waste, hence are most desired by the butchers. A full, smooth outline is an indication of flesh which is thick and even. Long legs, drooping rump, flat ribs, and narrow chest with open shoulders, giving a general angular and rough appearance, indicate a relatively large amount of waste and cheaper cuts in proportion to valuable meat.

*Quality.*—Quality is an evidence of refinement as opposed to coarseness. Usually it is associated with good breeding. Quality is important in the mutton sheep because it is associated also with ability to fatten rapidly, and because with sheep of good quality the percentage of waste is lower than with sheep of inferior quality. Good quality is indicated by a head and ears of medium size which appear lean and clean cut; fine, dense bone of medium size; mellow skin, pink in color; soft, silky hair on face and legs and those portions of the ears not covered by wool. Indications of a lack of quality are a general coarseness as shown by a large, rough head; coarse, large ears; a large, open frame, with coarse bone and rough joints; a thick, wrinkly skin covered with heavy, greasy wool, or a coat of wool that is harsh and coarse, and containing more or less kemp.

*Condition.*—The term "condition" or "finish" when used in connection with mutton sheep refers to the degree of fatness. Fat animals are preferred by the butcher because they dress a higher percentage of edible meat than do thin animals; their carcasses present a better appearance; they lose less weight in refrigeration and cooking; they possess better curing and keeping qualities; and the edible quality of the meat is improved when a considerable amount of fat is distributed throughout the lean. A good mutton sheep will have a smooth finish; that is, the fat will not be in bunches, but have an even distribution over the body.

### HEAD AND NECK.

*Muzzle.*—A large muzzle, with open nostrils, and lips strong, though thin, indicates thrift and a good capacity for food.

*Eyes.*—Eyes which are bright, full, and placid indicate health and a quiet disposition.

*Face.*—A broad head and a short face with clean-cut features denote quality and breeding character.

*Forehead.*—A forehead broad and full is an indication of intelligence. Width of forehead is also correlated with width of muzzle, indicating a good feeder, which may mean much in handling the sheep on farm or range.

*Ears.*—Alert ears are an indication of an active disposition. To indicate quality they should be of fine texture, of medium size, and covered with fine, soft hair where not covered by wool.

*Neck.*—Although the neck is not worth much as meat, it should be short and thick to correlate with other parts of the body.

### FORE QUARTERS.

*Shoulders.*—The shoulders should have an even covering of flesh and should be compact on top and filled out well in the crops and shoulder vein to give a smooth finish.

*Brisket.*—A wide, full breast is an indication of health and vigor. The brisket should project forward, but it should be neat and in proportion to the chest.

*Legs.*—They should be short and straight and set wide apart, having a broad arm, well fleshed, and showing as little waste as possible.

### BODY.

*Chest.*—A deep, full chest with a large heart girth is an indication of a strong constitution, as it means plenty of room for heart and lungs. Narrow-chested sheep are likely to lack thickness of flesh and to be in poor condition generally.

*Ribs.*—Well-sprung ribs not only make room for the vital organs but also give ample space for the laying on of flesh.

*Back.*—The spinal column should be well hidden with a thick covering of firm, smooth flesh. The back should be moderately short and straight, showing strength.

*Loin.*—In keeping with a strong back and well-sprung ribs, the lion should be short, broad, and thick to give a good connection between the thigh, or leg of mutton, and the back, and at the same time furnish a large amount of relatively high-priced meat.

### HIND QUARTERS.

*Hips.*—The hips should not stand out prominently. They should stand far apart and both should be on the same level.

*Rump.*—The rump should show a good length and a good width carried out well to the tail head. The rump should not droop toward either the tail or the thighs.

*Thighs.*—As the leg of mutton is the most valuable cut of meat, it is very important that the thighs should be deep and wide and full to the point of being plump.

*Twist.*—The leg of mutton should be not only plump and full on the outside but also in between the legs the twist should be filled well with flesh down to the hock, causing the legs to stand well apart.

*Legs.*—Mutton sheep should not have a leggy appearance, as long legs, with a lack of development in muscle, indicate a lack of constitution as well as a large proportion of waste in the carcass. Shortness of leg is associated with strength and smoothness, and fineness of shank is associated with quality.

### WOOL.

*Quantity.*—The factors which determine the amount of wool on sheep are its length and density and the uniformity in both over all parts of the body.

From a commercial point of view wools may be classified as short-stapled, or clothing wools, which are used in the manufacture of woolen goods; and long-stapled, or combing wools, which are used in the making of worsted goods. A fleece of long wool will give greater protection to a sheep in a cold country.

Density of the fleece refers to the closeness of fibers; it is determined with exactness by counting the number of fibers to a square inch. A dense fleece means not only more weight but it means also more protection for the sheep. To insure a heavy fleece the wool must be of fairly uniform length and density throughout the body.

*Quality.*—Although the highest quality and the greatest quantity can not be expected to go together both should be considered. For goods of fine grade the wool should be fine and soft, with a close, regular crimp. The term "crimp" is applied to the waves in the staple. Fineness of crimp is associated with fine quality. There should be uniformity of quality and texture.

*Condition.*—Condition with reference to the fleece pertains to its brightness and healthy appearance. The wool should be free from dead fibers and all foreign matter such as dirt and burs. The condition of the wool is determined to a great extent by the health of the sheep. Both the health of the animal and the condition of its fleece are indicated by the amount and character of the yolk, or oily secretion of the wool. Although too much yolk is not desired there should be sufficient to prevent any harsh, dry appearance or feeling.

## FEEDER SHEEP.

*Capacity v. condition.*—It should be obvious that the condition of a sheep will determine whether it shall be classified as a market or fat sheep or a feeder. All the points given in connection with the description of mutton sheep apply to feeders except that instead of looking for market condition, or finish, one pays more attention to capacity for food and ability to use it efficiently in the production of mutton. Experiments have shown that sheep which have been bred toward the type described under mutton sheep make greater gains for the amount of food eaten than do those of inferior breeding.

*Constitution and health.*—Feeder sheep not only should have a capacity for feed as shown by a well-developed barrel, but they also should give evidence of a strong constitution by having a wide, deep chest with ribs well sprung, making plenty of room for heart and lungs. Feeder sheep should be young and have their teeth in good shape. They can not use food efficiently if they have any form of diseases or if they are afflicted with lice or mites.

## WOOL SHEEP.

Although few sheep are bred to-day for their wool alone the relative value and amount of the wool upon the fine-wooled breeds in relation to their size and value in mutton production is responsible for their being considered as a wool type. In score cards for this type usually 45 points are given for wool, whereas in the score for mutton sheep 12 points are given for wool. While in the score for wool sheep the greater emphasis on wool is at the expense of mutton qualities, the tendency at present is to pay more attention to the meat-producing qualities of the fine-wooled breeds.

## BREEDING SHEEP.

*Breed type.*—While all breeds have the general form and characters of the type in which they are classed, all pure-bred sheep possess certain distinguishing features which are inherent in the breed and which receive the attention of breeders. These breed characters may have little value in themselves, yet they are a mark of breeding and give assurance that the animals will breed true to type. Included in such breed characteristics are such points as size, color markings, presence or absence of horns, and peculiarity of shape. These differences make it essential for the different breeds to have different score cards or standards of excellence which give consideration to these points. If one is selecting pure-bred sheep for breeding purposes, he must know the breed type as represented by the standards of excellence for the breed.[1]

*Sex character.*—Whether one is breeding pure-bred sheep or is engaged in grading up a common flock, in the selection of breeding stock he should consider the qualities the market demands for wool and mutton. In addition to the application of market and breed standards, stock intended for breeding should be considered from the point of view of prepotency in transmitting their good features and prolificacy in reproduction. These qualities are indicated by what is known as sex character.

*The ewe.*—To be a long-lived, regular, and prepotent breeder the ewe must have a strong constitution and show a strong maternal nature and present a feminine appearance. The ewe should have finer features about the head and a more slender neck than the ram. She should have plenty of room for the growth of the developing fetus. To provide well for early maturing lambs, she should give an abundance of milk. Breeding ewes should never be excessively fat, as they are so often in the show ring.

*The ram.*—The ram should be pure bred and show breed character and quality in strong form, because it is largely through him that improvement is secured for the flock. To be prepotent, the ram also must show a good deal of sex character; that is, there should be no doubt at first glance that he is a ram. He should have greater size than the ewe and a decidedly masculine appearance, indicated by a general burliness of the head, with a thickness of neck giving a suggestion of massiveness. He should have every indication of boldness, vim, and vigor as denoted by a brisk movement and a bold, energetic look through a bright, clear eye. A breeding ram should not be excessively fat, yet he should at all times be kept in good condition.

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[1] Score cards for the leading breeds may be obtained from the secretaries of the breed associations listed in Farmers' Bulletin 576, Breeds of Sheep for the Farm.

## PRACTICE JUDGING.

*Aims.*—The classroom instruction is but preliminary to the more important phase of the subject—practice with the sheep. Although the instructor may agree that better results may be obtained by studying the sheep than by studying about them in books, it is well to have in mind very definite aims in the practical work and have a definite plan of procedure. The chief purposes in giving practice are: (1) To make application of classroom instruction, (2) to gain concrete experience and observation upon which to base further discussion, and (3) to gain skill in observation and judgment.

*Preparing for a judging trip.*—As a rule, secondary schools must depend upon neighboring farms for stock-judging material. The teacher should know the live stock in the neighborhood of the school, that he may select animals suitable to his purposes. He should plan each trip with a definite purpose in view and know what he will have to work with. He should secure the consent of the owner and make arrangement to have the sheep in suitable inclosures so that no time will be lost. Wet, muddy barnyards should be avoided, and if there is danger of unfavorable weather, provision should be made for working under cover. With all such preparations made in advance, the class will need at least a double period for effective work in judging if the students have to go any great distance from the school. The teacher should be familiar with the animals he intends to use. In the case of comparative judging it is especially important that the teacher should be well acquainted with the animals and their relative merits. To aid the students in establishing high ideals, it is well at first to select animals which approach perfection.

*Use of the score card.*—The first practice judging should involve the use of the score card for a general type. It is assumed that in the classroom the students will become familiar with the card and the naming of parts. After the students have been shown how to handle and examine the animal they may make individual scores. Each student should work by himself. Conversation and comparison of scores should be avoided while the work is being done. The teacher should be able to make a score of the animal in much less time than the students and have the remainder of the time to supervise their work. Each student should make an estimate of the weight of the animal, to be checked by the use of scales if convenient. The student should have well fixed in his mind an ideal mutton sheep or the ideal of the type to be judged. The card will give the score for perfection in the various points; the student will enter a score which represents the points which he judges the animal to be worth. The sum of these points gives the score of the animal. It should be remembered that the use of the card is chiefly for the purpose of

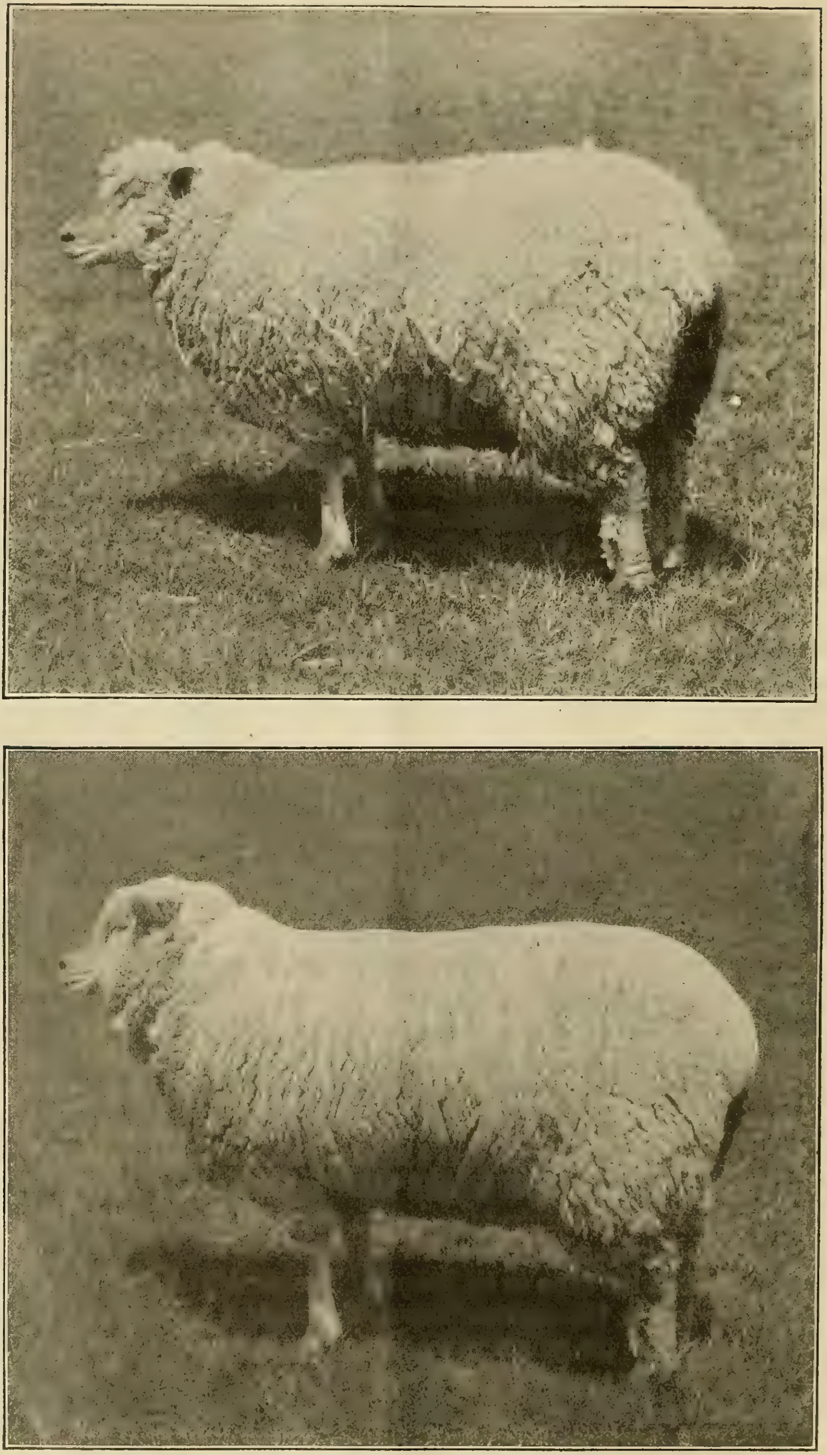


FIG. 8.—Sheep before trimming (above); after trimming (below).

training the student in observation, hence no details should be overlooked. The value of the score card in judging animals depends largely upon the care with which it is used. The following percentages are suggested as a basis for scoring: 1.0, perfect; 0.9, very slight defect; 0.8, slight defect; 0.7, defective; 0.6, marked defect; and 0.5, poor. The number of points given for any particular part of the animal should be multiplied by the percentage rating given that point in the mind of the student. For example, loin is given six points and the animal examined is found to be defective. Six times 0.7 equals 4.2, which represents the score for the loin. In this manner the various parts of the body may be given a proportional score.

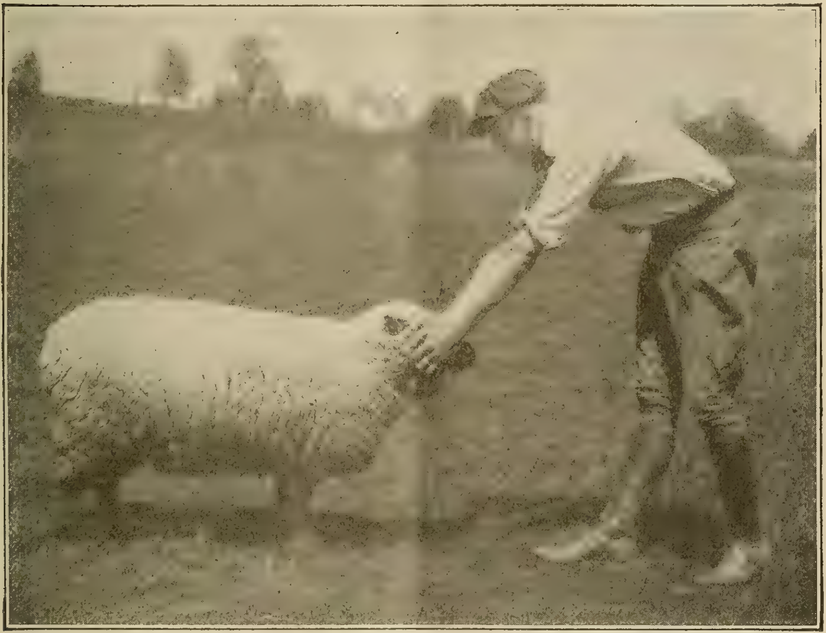


FIG. 9.—Dragging the sheep. The wrong way to move a sheep.

*How to handle sheep.*—Because of the covering of wool the hand must be used freely in judging sheep. The use of the hand is especially important with fat sheep trimmed for the showroom (fig. 8). For this reason the teacher should select for judging sheep which are accustomed to being handled. The students should be cautioned not to handle the sheep roughly by grasping the wool (fig. 9), but to grasp the skin under the throat carefully with one hand and with the other to press at the tail head to move it to the position desired (fig. 10). In order not to disturb the wool and injure the sensitive skin, the fingers should be held together and the hand kept flat in parting the wool to note condition of wool and skin. With beginning students an excellent plan is to use a shorn sheep in order that they may get correct impressions of body form. Although the diagram on page 4 (fig. 4) will aid in giving an idea of the outline of the sheep in fleece to that of the shorn animal, it will not have value equal to a comparison of a sheep in full fleece with one that has been shorn (fig. 11).

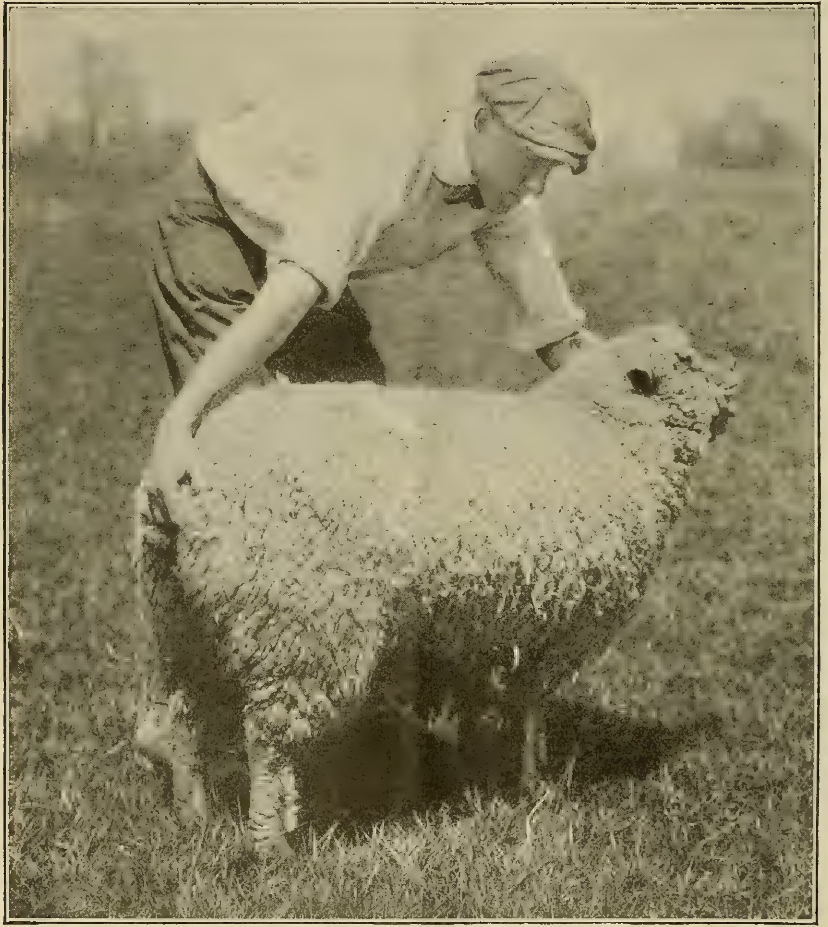
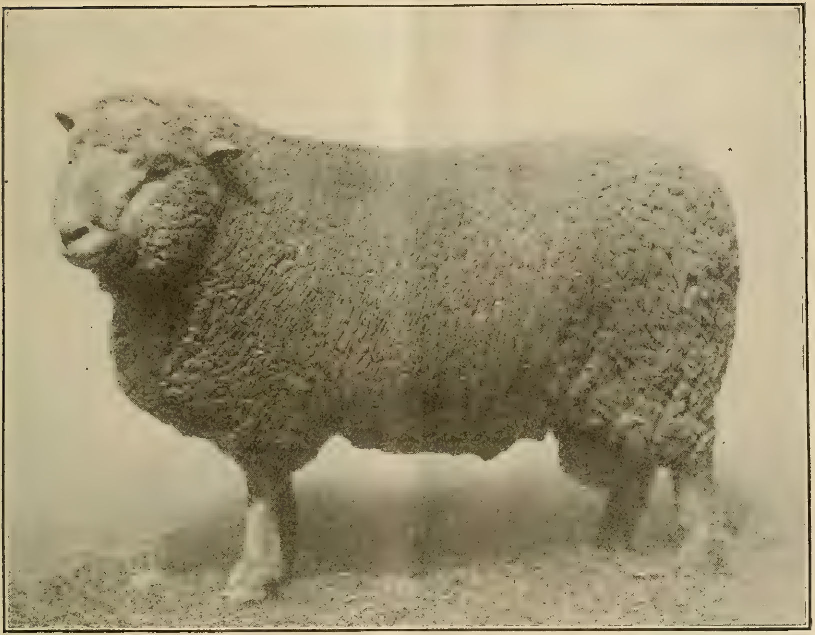


FIG. 10.—The right way to move a sheep.

If the students have opportunity to work with sheep fitted for the show ring, they may profit also by a comparison of a sheep which has been trimmed with one which has not.

*Method of examination.*—In using the score card the students should have a systematic, definite mode of procedure. The first observations will be of necessity general ones, to be followed by a more



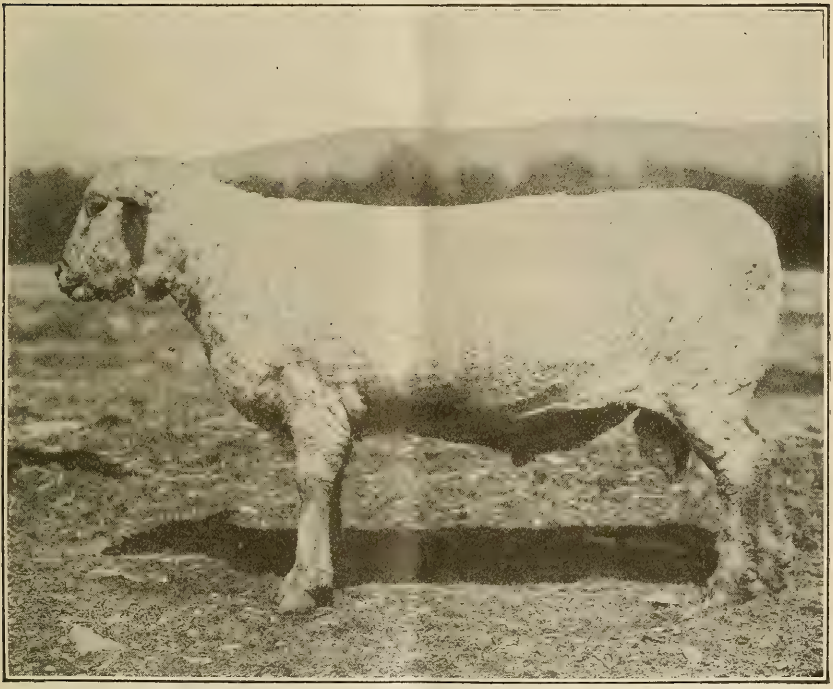


FIG. 11.—Sheep before shearing (above); after shearing (below).

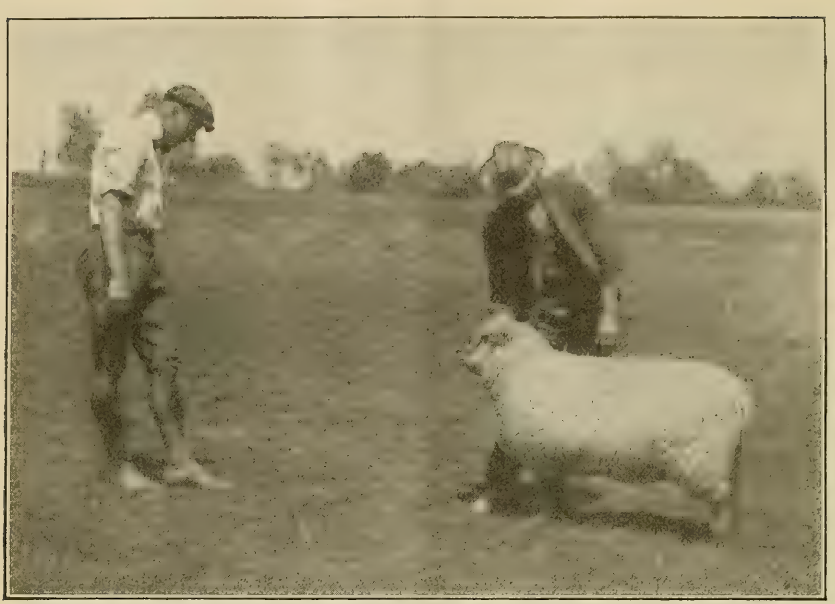


FIG. 12.—Noting breed character and general conformation from a distance.

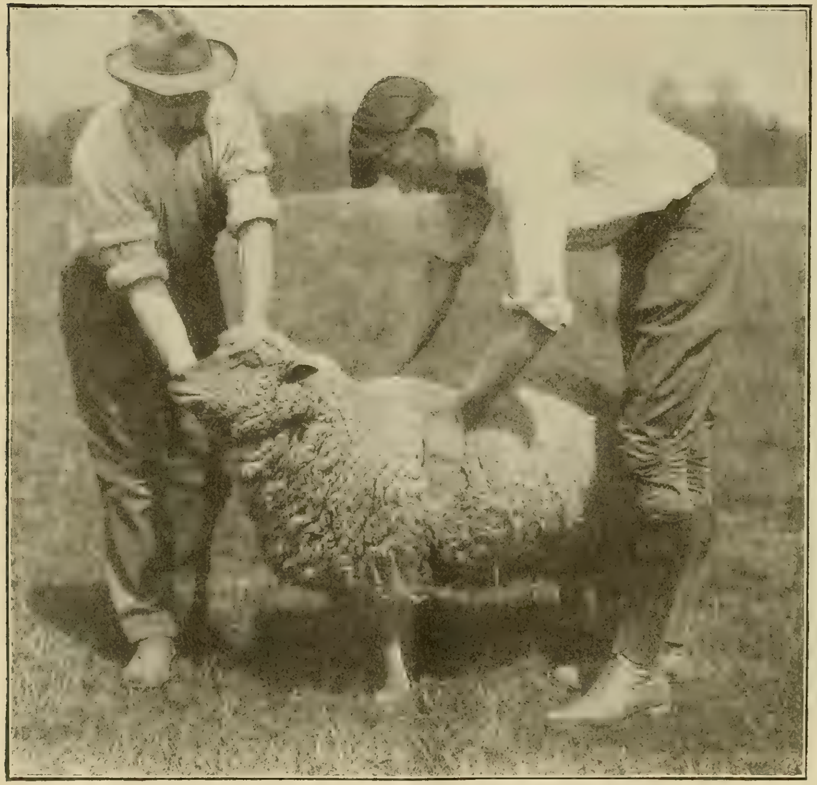


FIG. 13.—Noting the flesh covering of the shoulder vein.

detailed examination. The importance of first impressions should be emphasized. To note the general appearance of a sheep the students should not get too close. They will get a better impression of the animal as a whole from a distance of at least 10 feet (fig. 12). From this distance the general form of the animal may be noted. After the general form has been noted the legs and face may be examined as to cleanness of bone and the nature of the hair as an indication of quality. Scoring as to condition well may be left until the parts involved have been examined more in detail. The more detailed examination then may proceed, beginning with the head and continuing over the whole body. After the age has been estimated as directed below, while holding the sheep by the throat with one hand, the other hand may aid the eye in determining if the head is of the proper shape with good width of forehead, sound eyes, and no appearance of horns in breeds supposed to be hornless. If the sheep has horns they should spring clear from the head. The student should next feel the fullness of the neck, noting its length and the manner in which it meets the shoulder at the shoulder vein and note

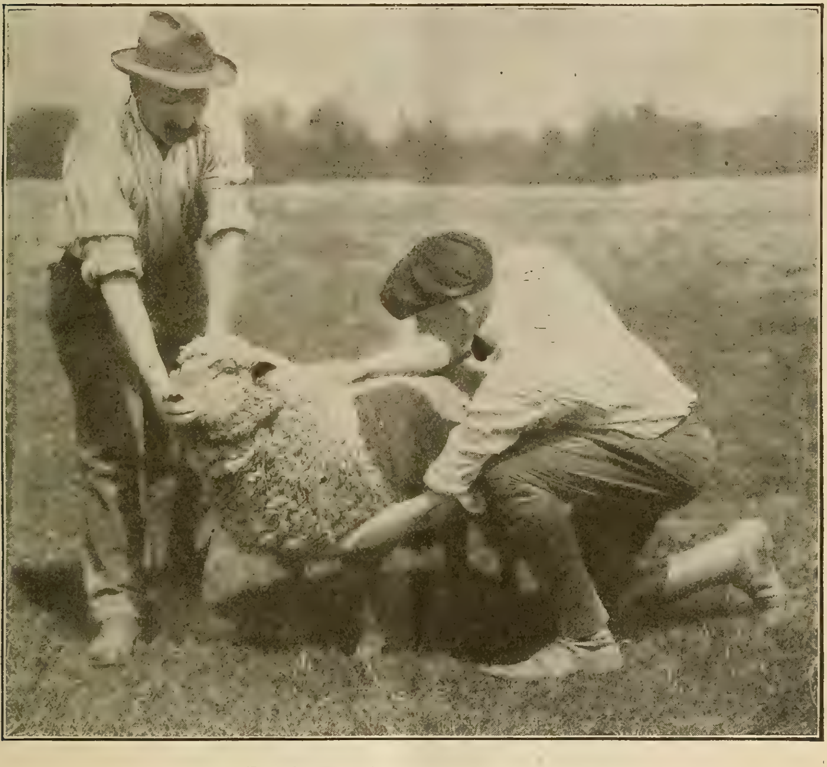


FIG. 14.—Noting the depth of chest.

the fullness of the shoulder vein. Next observe the shoulder, noting the fleshy covering on the top and along the sides (fig. 13), and then pass down to the brisket, noting its width, and then gain an idea of the depth and width of chest by placing one hand on the floor of the chest and the other on the top of the shoulders (fig. 14). Passing back of the shoulders, note the width in this region, heart girth (fig. 15), and the manner in which the ribs are sprung. Then with one hand follow the line back of the shoulder to the tail head, noting the straightness and coupling of the back indicating its strength, also its width and the depth, evenness, and firmness of the flesh covering. Special attention should be given the width of the loin and the depth and quality of its covering (fig. 16). Before passing to the hindquarters the general capacity of the middle should be noted, attention being given to the flesh covering. Note width of hips and the length, fullness, and width of rump (fig. 17). Then with both hands (fig. 18) examine the leg of mutton, carefully noting its size, fullness, thickness, and firmness. With one hand between the legs and the other at the tail head note the depth and breadth of the twist (fig. 19).

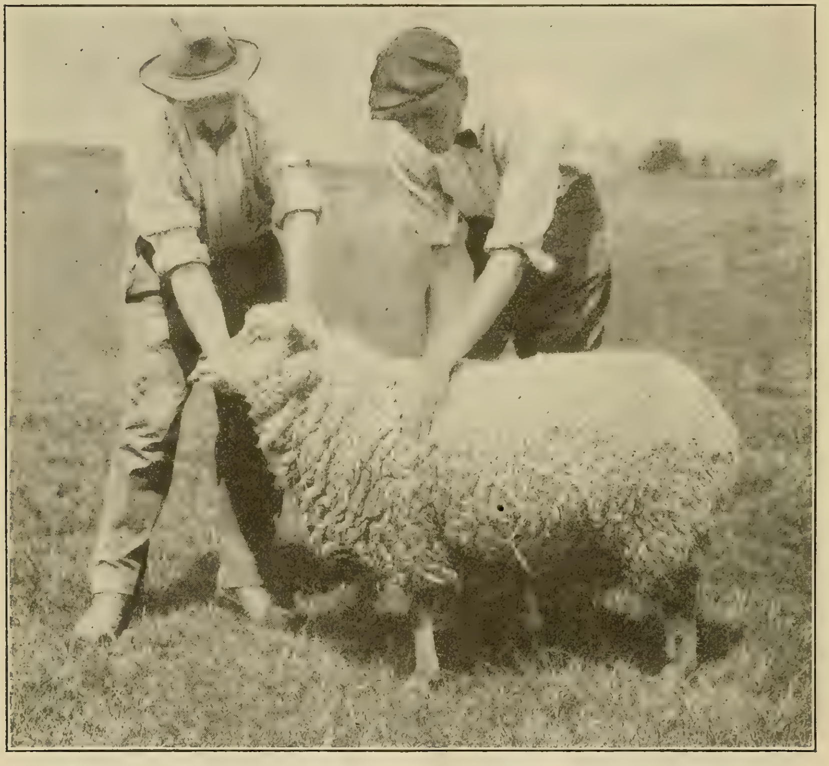


FIG. 15.—Noting the capacity of heart girth.

In examining the fleece to note its quantity, quality, and condition it should be opened first just above the point of the shoulder (fig. 20), as in this region the best wool is to be found. The thigh (fig. 21) should be examined next, as upon this region grows the poorest and coarsest of the fleece. As the belly is often covered but lightly it should be examined also.

*Estimating the age of sheep.*—In addition to the sets of molar teeth at the back of both upper and lower jaws the sheep has a set of eight incisors on the lower jaw which work against a tough fibrous pad on the upper jaw as in the case of the cow. The age of a sheep may be estimated by the appearance of these incisors up to the time it is four or five years old. By the time the sheep is four weeks old it has eight temporary incisors, or milk teeth. When the sheep is slightly over one year old the central pair of incisors is replaced by permanent teeth which are broader and wider than the temporary ones. When the sheep is two years old the next pair is replaced; the third paid when the sheep is nearly three years old; and the fourth or corner pair when the sheep is between four and five years old, hence a

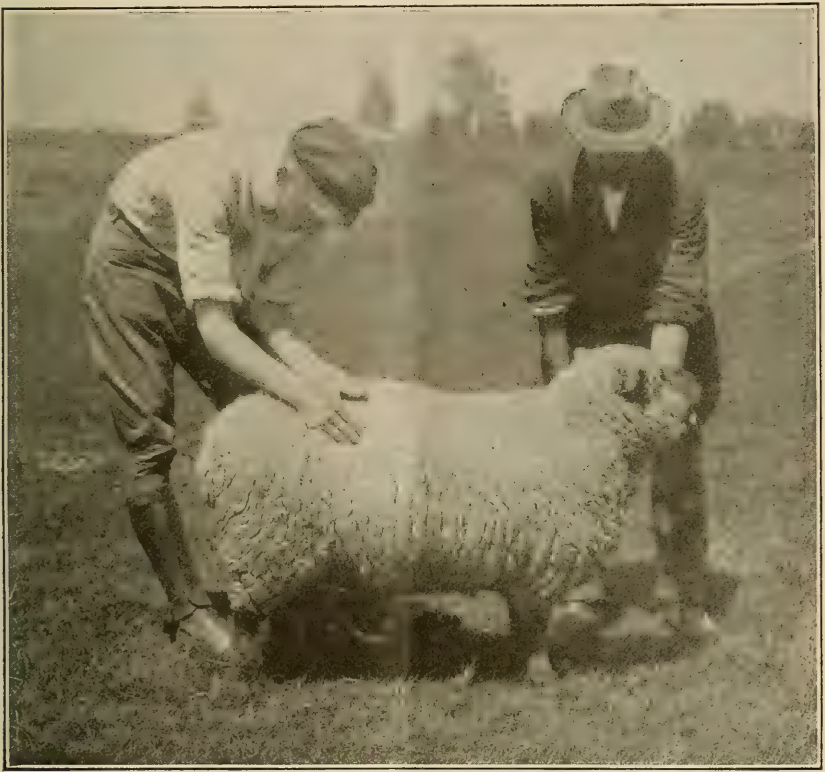


FIG. 16.—Noting width at loin.

full set of permanent incisors will indicate that the sheep is at least four years old. If the sheep are kept in high condition, as show sheep often are, the process of replacing the milk teeth with the permanent ones will be hastened; on the contrary, a lack of proper feed will retard the process. Although it is not possible to tell the age of sheep by the teeth with accuracy after they have a full set, it may be determined roughly by the condition of the teeth. As the sheep gets older the teeth are worn down. As the teeth may become broken and lost, thus affecting the ability of the sheep to feed, all older sheep should be examined to note if the teeth are in working condition.

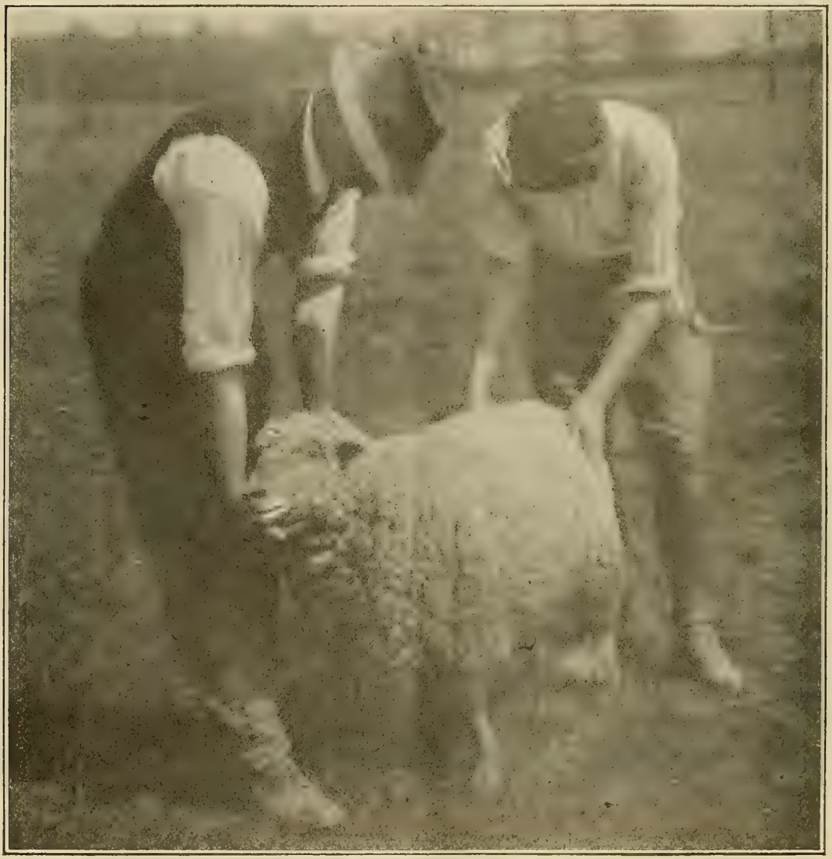


FIG. 17.—Noting width of rump.

In examining the mouths of sheep one should be patient and not be rough in the exertion of force. With one hand holding the head against the thigh to steady it, the lips should be parted with the first two fingers of the other hand (fig. 22). If this is done quietly and gently, there will be little difficulty in exposing the teeth.

*Comparative judging.*—(Fig. 23.) Repeated practice with the score card should be but preliminary to the method used in the show ring, that of comparison and placing according to merit. The student who has used the score card carefully with a number of sheep should be prepared to take in the general conformation and detect the details which indicate the worth of the animal. In trying out the judgment of the students in comparative judging, it is well to select for the first practice four sheep of marked difference in important characters. As skill is developed animals more nearly equal may be chosen. Each animal should be numbered or lettered and the students given a brief time in which to place them according to their relative merit with respect to such important general characteristics as constitution, market condition, or condition of fleece. After they have placed them according to judgment from one point of view they should then place them with all characteristics considered. Time equal to that given for the final placing should be given for the students for writing their reasons for such placing. As students very often do not know how to state their reasons definitely, the following form filled out is suggested for this exercise:

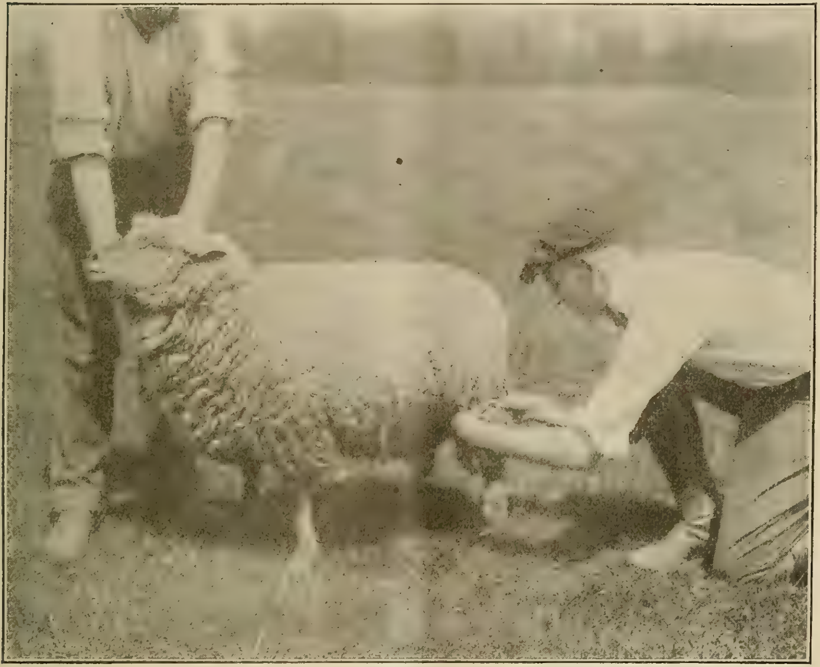


FIG. 18.—Examining the leg of mutton with both hands.

Name of student: William Smith. Date, February 9, 1917.
Class of animals: Mutton wethers.

Placing: First, C; second, D; third, A; fourth, B.

1. I placed C over D because he approached more nearly the ideal mutton form and shows a smoother covering of flesh, etc.

2. I placed D over A because he shows finer quality and has a heavier fleece of better quality, etc.

3. I placed A over B because he shows a better leg of mutton and has a wider chest and heart girth, indicating a stronger constitution, etc.

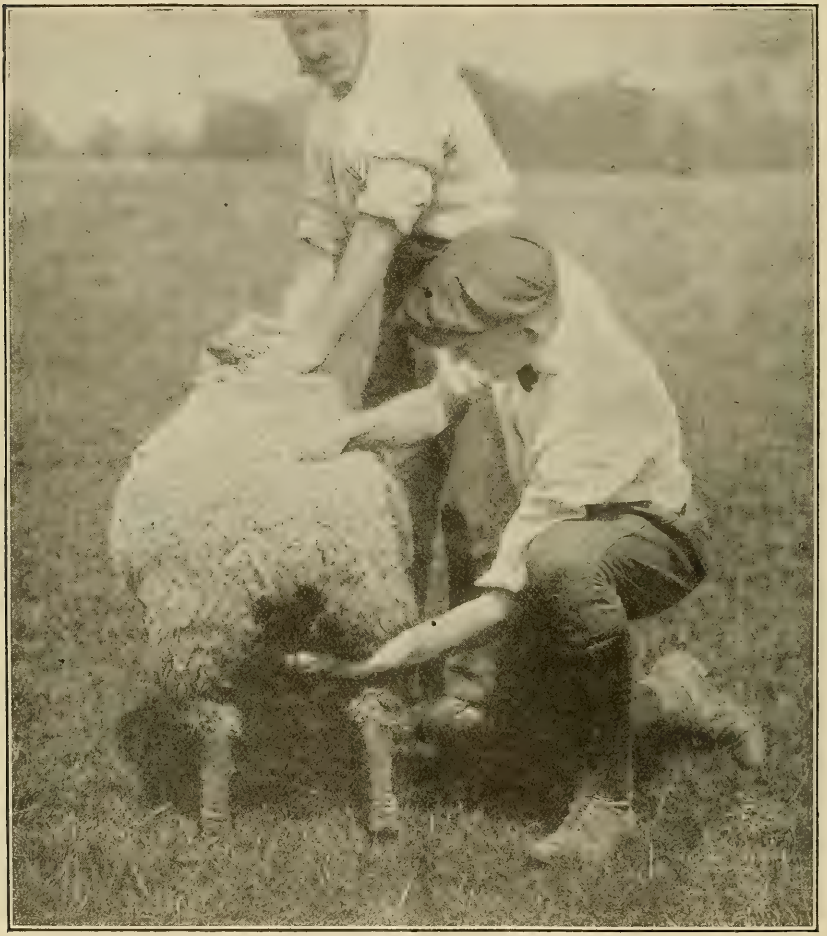


FIG. 19.—Noting depth and breadth of twist.

*Judging contests.*—The contest idea may be used to arouse interest in this work and to develop school spirit. From the students which do the best individual work a team of three to five members is selected to represent the school in judging sheep and other animals at county and State fairs. Although much can be done toward arousing interest in the agricultural work and some good advertising may be secured for the school by a competent team, such a team should not be trained at the expense of neglect to students in the regular work. The work in stock judging should be a means toward the end of training farmers and should not be considered in any sense an end in itself.

Whether the school enters a judging competition or not, the teacher may gain a great deal by taking his class to good fairs and livestock exhibitions. Such visits should be definitely planned and supervised to yield the best educational results. Under the direction of the teacher the students should learn much of the various types and breeds and note the methods used by expert judges. Special attention should be given the work of the judges, particularly to the explanations of their placings.

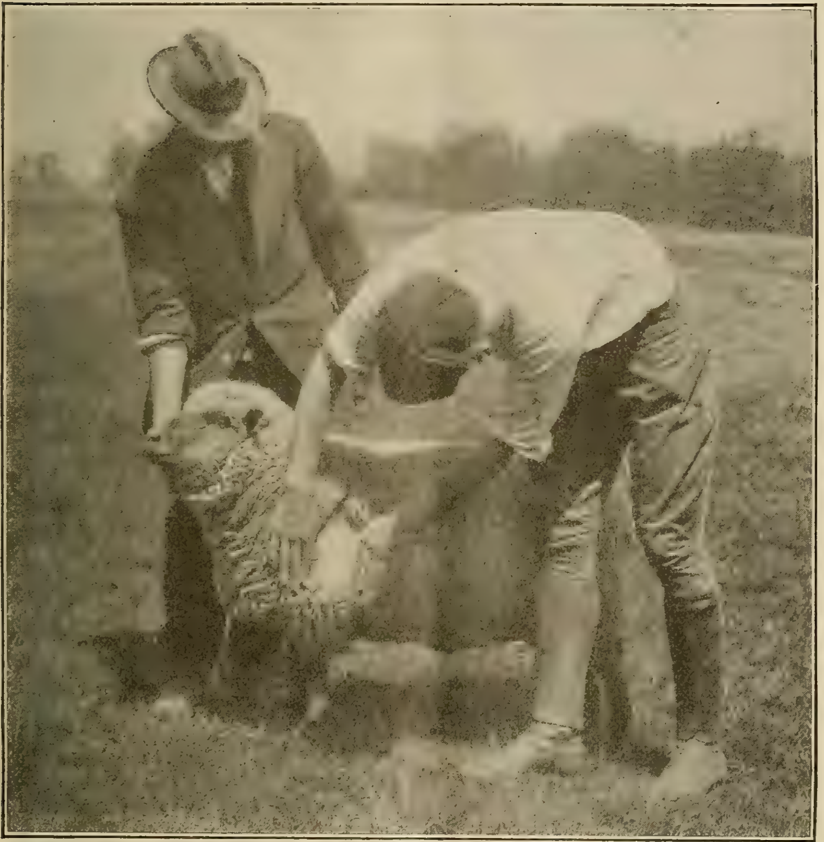


FIG. 20.—Examining the fleece upon the shoulder.

At some of the schools local fairs are held under the direction of the school. Such exhibits not only furnish material for stock judging, but also should do much to arouse interest on the part of both students and patrons.

*Practical applications.*—It should be borne in mind that the end to be reached in teaching stock judging in secondary schools is not to train judges for the show ring, but to develop judgment which may be used in selecting sheep for breeding and feeding purposes upon the farm. After practice has been given with the score card and in placing sheep by the comparative method it will be an excellent thing to have the students apply their training as farmers. If flocks of breeding and feeding sheep are accessible each student may be assigned the problem of selecting a stated number of animals best suited to a particular stated purpose. Following a study of market conditions, prices may be assigned to the animals selected. The

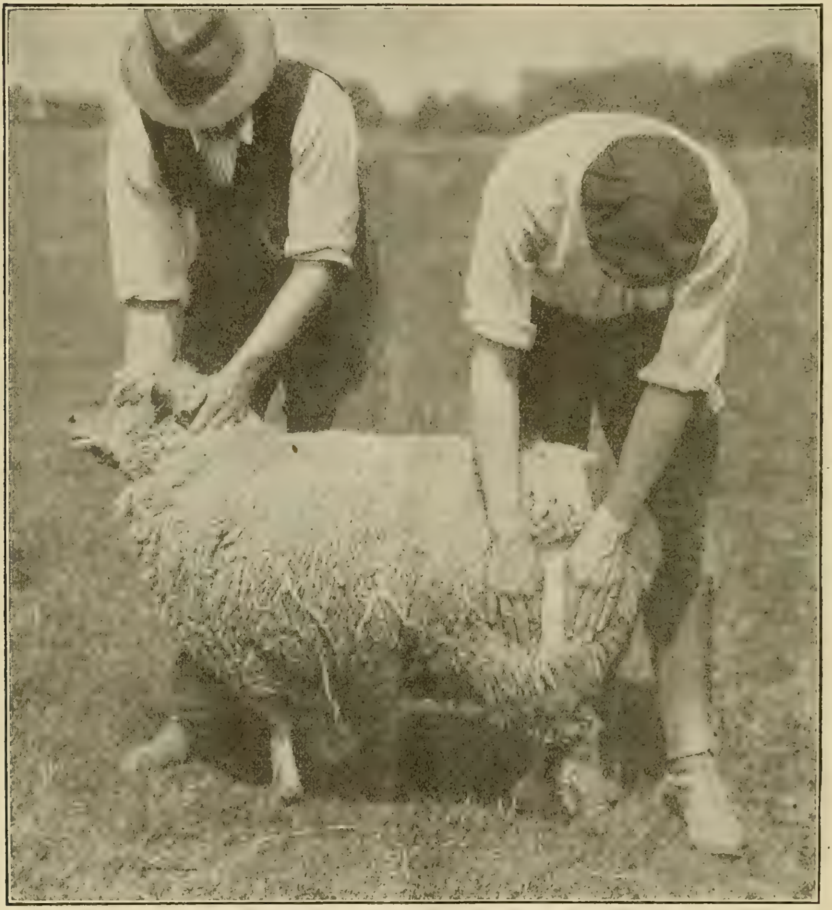


FIG. 21.—Examining the fleece upon the thigh.

judgment of the students then may be compared with that of the owner, the teacher, or some other person more competent. Whereever the students are selecting sheep for their home-project work their training may be applied in a more vital manner, as the success of the student will be involved in a financial way.

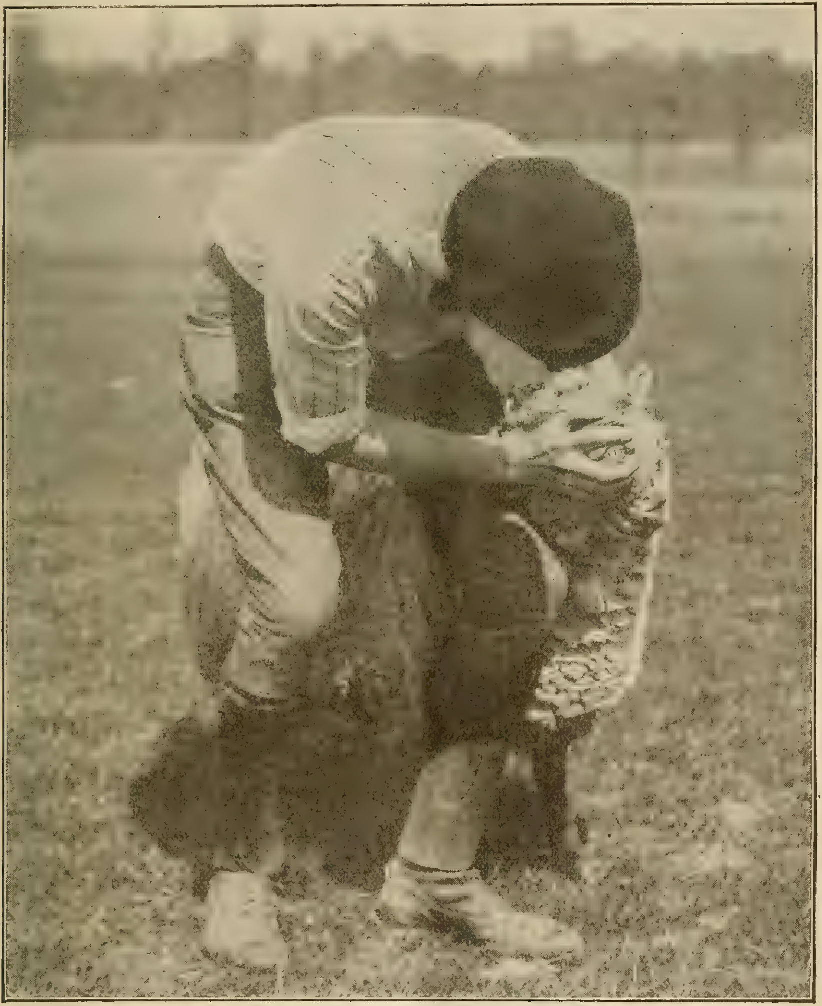


FIG. 22.—Estimating the age of a sheep.

*Grading wool.*—Although a study of wool as a product is not strictly a phrase of judging sheep, it may be made a very helpful adjunct to such work. A practical study of market grades and classes of wool will aid the student in judging wool upon the sheep and develop an appreciation of greater care in handling sheep with regard to maintaining a better standard of wool. Department Bulletin 206, The Woolgrower and the Wool Trade, may be made a basis for such a study. Samples of wool may be brought from the home farms or from local warehousemen. It may be possible to secure a set of samples showing standard classes and grades from dealers or manufacturers. If such are not obtained, the illustrations of the bulletin, with the descriptive matter, will prove sufficiently helpful to make the work worth while. Each student should be required to classify the samples obtained and give written reasons for his placing independently.

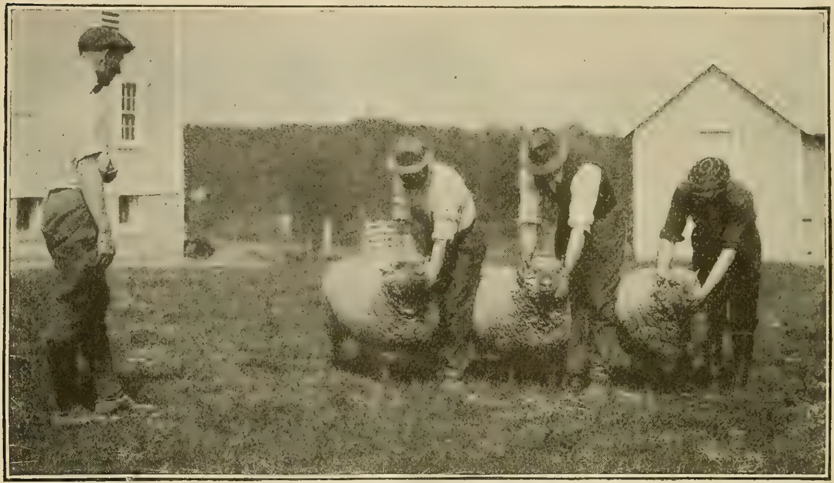


FIG. 23.—Sheep arranged for comparative judging.

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UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 594**

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief

Washington, D. C. February 21, 1918

# GEOGRAPHY OF WHEAT PRICES.

## SUMMARY OF CONDITIONS AFFECTING FARM PRICES OF WHEAT IN DIFFERENT PARTS OF THE UNITED STATES.

By L. B. Zapoleon,
*Division of Crop Records.*

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## SIGNIFICANCE OF REGIONAL PRICE DIFFERENCES.

Extreme geographic differences prevail in prices paid to farmers.
Farm prices increase or decrease in well-defined directions, varying with each item of production.
Character of the data employed; counties the basis of measurement.

The prices paid to farmers for a given product vary so greatly throughout the United States, and the variations are so closely interwoven with changing economic conditions as to indicate a field of research of practical value and economic interest. That wide differences should be found throughout the country in the prices of certain perishable farm products is to be expected. But agricultural staples not perishable in character, and of general consumption, exhibit a like disparity; even when price differences due to grade or quality are relatively small, more than 100 per cent variation frequently obtains throughout producing regions of the United States. Neighboring counties often show distinct differences in price.

Two sets of factors are concerned in producing variations in farm or producers' price. One set has to do with the general price level of a given product; the other set is regional in its effect and divides the United States into sections according to price disparities. Climatic changes (affecting the outcome of the harvest), the outbreak of war, changes in the purchasing value of money, and other factors produce price changes that are nation-wide in extent. But differences in freight rates and transportation facilities, proximity to or remoteness from consuming territories, and other factors in the relationship of local to general distributive conditions, though affecting smaller areas, are equally potent and more stable in their influence. The latter class of factors—those dividing the United States into zones according to the price paid farmers for a given product—presents a field that is only partially developed.

Obviously farm price is a potent factor in adjustments of agricultural production. Just as climatic limitations on agriculture are shown on maps, so do farm prices, on sufficiently detailed maps, align themselves into zones, since price variations increase or decrease in well-defined directions. But this local price advantage or disadvantage varies with each product, according to its characteristics and commercial movement; the extent and regularity of zones having equal price figures change with each crop, and so also do the direction and rate of increase. Thus, southern farmers, raising varieties of wheat mostly softer than those of the North and West, receive on an average up to 60 cents per bushel more. The lowest wheat prices occur in regions marked by high prices of corn. Eastern farmers receive decidedly higher price averages for bulky commodities, such as hay, than for cereals. Much irregularity occurs in the prices of products wherein local consumption is important, such as corn or vegetables; greater stability, however, prevails in prices of wheat and oats. Within each State there is usually a variation of at least 20 cents per bushel in corn prices, which is about the cost of sending corn from Chicago to Liverpool, under normal conditions.

This publication deals with the wide variation in the producers' price of wheat throughout the continental United States. State price averages usually embrace large areas and dissimilar conditions; therefore the county has been used as the smallest available working area wherein approximately similar conditions of supply and demand prevail. As the ratios of sectional prices fluctuate with unusual market conditions, an average for the five years, 1910–1914, was employed to differentiate normal from spasmodic differences. Basic figures for each of the five years were compiled from an annual total of about 30,000 township reports. The result constitutes, in effect, a survey of the geography of wheat prices and price factors.

In assembling the material herein, a threefold plan has been pursued:

First, a tabular presentation of the price averages, by counties (Appendix, p. 34) is supplemented by maps and graphs, to show geographic price zones and related factors.

Second, the most suggestive bearings of the indicated price differences are outlined. In an empirical method of treatment only is this phase attempted, for price factors are complex, frequently interdependent, and are not susceptible of absolute measurement. To this has been added a brief retrospective view of price factors from 1871 to 1915, for the purpose of showing present tendencies through their indicated development.

Finally, gross price has been contrasted with actual returns by coordinating prices, yields, and cost of production per bushel and per acre.

## SURVEY OF GEOGRAPHY OF WHEAT PRICES.

From a minimum in Idaho and Montana, prices paid wheat growers graduate upward toward the coasts, with maximum price in the southeast.

Price increases follow direction of commercial wheat movement from exporting to importing regions.

Map 1, which is given opposite, has been condensed to a 10 cent price unit, in order to delimit the general price zones without the intrusion of minor local variations. Blank spaces indicate areas of little or no production, according to the 1909 census. Figures within each State show estimated wheat surplus or deficiency (i. e., difference between production and consumption within the State), indicating the direction of the commercial wheat movement.

The minimum price paid wheat growers occurs within the areas of surplus wheat production, in central Montana and eastern Idaho. With a high rail and lower ocean freight rate eastward, and a shorter rail but higher ocean freight westward, this territory is most disadvantageously situated as to foreign and domestic wheat markets. Radiating from this region, prices graduate upward in every direction until the maximum, toward the coasts, is reached. Generally speaking, the surplus-producing areas have the lowest prices, and the converse also is true. From the described region of lowest prices two main currents, Pacific and eastward, are apparent, following closely the direction of wheat shipments.

The Pacific wheat movement is of much smaller volume than the eastward traffic. The surplus is concentrated in a relatively small area in the Northwest. Westward from this area prices increase steadily toward the Pacific seaboard. Prices rise also southward toward areas of insufficient wheat production, the maximum price being reached in southern California.

The wheat movement eastward attains much larger proportions. The surplus swells to tremendous volume, progressing through the trans-Mississippi wheat belt. This surplus, in the form either of wheat or of wheat flour, supplements deficient production to the east and south, and comprises the bulk of the export wheat. Here again prices augment in the direction of the wheat flow, increasing slowly eastward, much more rapidly and irregularly southward, in which direction the wheat movement is of less volume. The highest farm prices of wheat are reached in the southeast.

## WHEAT VERSUS CORN AND OATS—PRICE ZONES COMPARED.

Corn—Area of minimum farm price in adjoining sections of Iowa, Nebraska, South Dakota, and Minnesota.

Oats—Area of minimum farm price immediately north of that of corn.

Comparison of the farm price zones of wheat with those of corn and oats discloses suggestive differences. The production of corn and oats is much greater, yet a smaller percentage enters into the commercial movement, the major part being retained on the farms. Population requirements do not directly dominate price progressions of corn and oats as they do those of wheat.

The region of lowest corn price is seen in the adjoining sections of Iowa, Nebraska, South Dakota, and Minnesota. From this area prices increase in every direction at a much more rapid rate than in the case of wheat and with much greater local variation. Within most States a consistent variation of at least 20 cents per bushel obtains in corn prices. From the region where corn is cheapest prices augment in the direction of the lowest wheat prices; that is, westward and northward, as well as to the other points of the compass, with highest corn prices in the southeast and southwest.

Although more widely diffused, oats are somewhat similar to wheat in being a northern crop. The lowest price areas, directly north of those of corn, are in western Minnesota and eastern North Dakota; from this area prices increase in every direction. The price accretions of oats are more notable toward the south, rather than east or west; and price differences are less marked, region by region.

## PRINCIPAL CAUSES UNDERLYING PRICE DIFFERENCES.

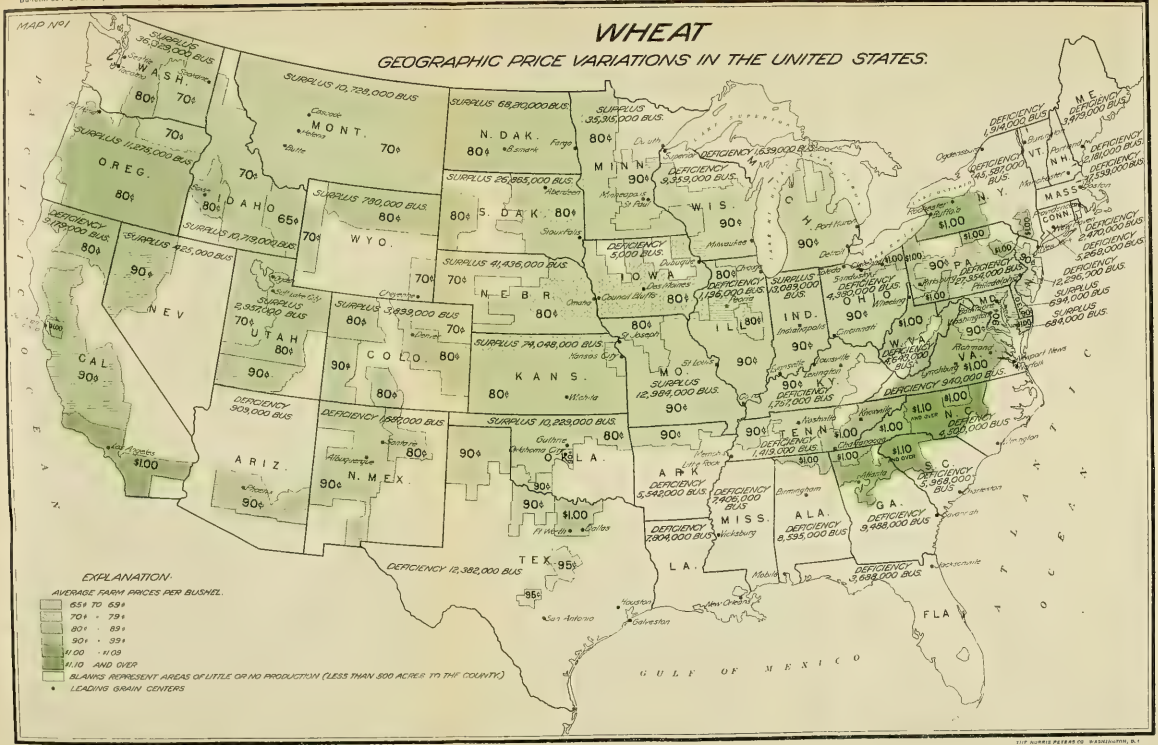
Connection between wheat prices and movement of wheat from sparsely populated surplus areas to those of deficient production.

Population, wheat production, requirements, surplus or deficiency, wheat milled; general review.

Analysis of elements in distributive movement; by States and divisions.

In the price graduations of wheat the basic consideration appears in that, whereas wheat is destined for human consumption, wheat growing has been steadily relegated to the less densely populated

(NOTE—The difference in price between any two regions may be regarded as practically stable, regardless of changes in the prices themselves. This map serves as an index of geographic variation in farm prices.)



THE NORRIS PETERS CO. WASHINGTON, D. C.

CONDENSED MAP SHOWING
- Farm prices per bushel. Average of 1910-1914 to show normal geographic variation.
- Usual wheat surplus or deficiency by states, as evidenced by average of five years 1910-1914. Indicates direction of commercial wheat movement.
- Points of largest wheat accumulation.

regions. The flow of wheat is then from these areas to those of denser population and deficient supply. Price maps reflect regularly geographic relationship to this movement, the lowest prices appearing in the surplus-producing areas farthest from European markets or in those most unfavorably placed in the distributive channels.

Map 2 shows the distribution of wheat production in the census year 1909. It will be noted that while wheat raising is generally diffused from ocean to ocean (except in the southernmost tier of States), only certain States which may be roughly described as lying west of the Mississippi and north of the thirty-seventh parallel produce more than their requirements for food and seed.

Table I (p. 8) presents in condensed form data relating to the geographic price alignments of wheat. To obtain representative measurements a five-year average was employed (1911–1915). States have also been grouped by sections of the country to permit of a general view. Population, wheat production, wheat requirements for food and seed, and surplus or deficiency are given in absolute figures as well as percentages of the United States totals. The relation of production to population in each unit is indicated by the per capita figures. Commercial movement of wheat (with which farm prices are closely identified) is indicated by "shipments out of counties where grown;" and a rough characterization of this traffic, whether it be in the form of wheat or wheat flour, is obtained by comparing the census data regarding wheat ground in merchant mills during the calendar year 1914 with figures for production and average requirements.

A striking feature of this sectional grouping is the degree of the national dependence for wheat supplies upon the West North Central States, constituting about 17 per cent of the total area, and the concentration of production within a few States west of the Missisippi. The entire region east of the Mississippi, in addition to the southwest, produces much less wheat than it consumes. Here, too, the highest farm prices prevail. The North Atlantic States grow only about one-fifth of their requirements, comparing with Great Britain in this respect. Most notably deficient in production (showing also the lowest per capita consumption) is the territory comprised in the Atlantic and the Southern States (bounded by the Ohio and the Mississippi Rivers) and the West South Central section, 25 States in all. These regions grow only 16 per cent of the national wheat (1911–1915), but contain 56 per cent of the total farm lands, 49 per cent of the total improved land (1910 census), and 60 per cent of the total population. In round numbers they total: Wheat requirements, 305 million bushels; production, 129 million; and deficiency, 176 million bushels. To the wheat drawn here to supply this shortage should be added an approximately equal quantity, on an average, going to the seaports for export, also less than 100 million bushels of Canadian wheat shipped in bond. The deficit would be considerably augmented by omitting Oklahoma with its production of 26 million and surplus of 12 million bushels. A total of the States raising insufficient wheat, regardless of sectional grouping, gives less than 19 per cent of the wheat production and 68 per cent of the population.

It is noteworthy that the merchant flour mills in the Atlantic and the Southern States mill over 25 per cent of the total wheat, as against 16 per cent of the wheat produced. These figures would be increased considerably by the addition of wheat ground in custom mills, particularly important in the South, but figures for which are not available. In this section the fraction which is shipped out of counties where grown is small, indicating that the bulk of the wheat raised is retained for local use and does not enter into trade channels.

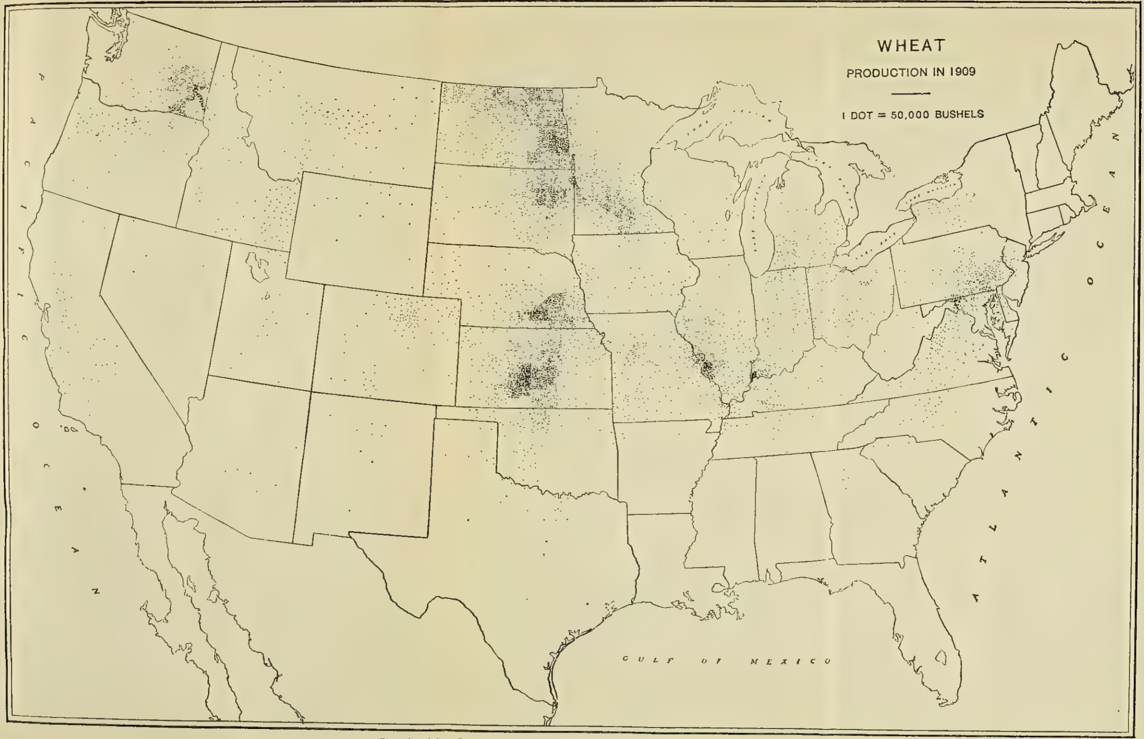
The production in the East North Central States is about offset by the requirements; the single surplus State of Indiana brings up the average for the section, other States in this division usually being deficiency States.

The residual territory west of the Mississippi, embracing the surplus wheat areas, produces some 550 out of the total 800 million bushels, or about 69 per cent, though it has but 38 per cent of the farm lands and 20 per cent of the total population. In this surplus wheat region the vast area in the Mountain States, of which only about 2 per cent was improved in 1909, is as yet relatively unimportant as to surplus wheat, although developing at a rapid pace. The western surplus supplies the deficiency of the other sections as well as the bulk of the export wheat. A very small percentage is shipped via Canada, an increasing proportion moves toward the Gulf ports, and by far the larger part moves eastward, either milled en route or as wheat.

Figure 1 is added to throw into relief the proportionate significance of factors in the table discussed.

Reference to Table I will show that per capita wheat consumption declines as prices increase, ranging from 4 bushels per capita in some Southern States to 7.2 bushels in Montana and South Dakota.

**Note.—Differences in price as shown or discussed in this bulletin are not intended to refer to present war conditions; they are based upon prices for the years 1910 to 1914.**



Reproduced from Statistical Atlas of the United States, 1914 (Bureau of the Census).

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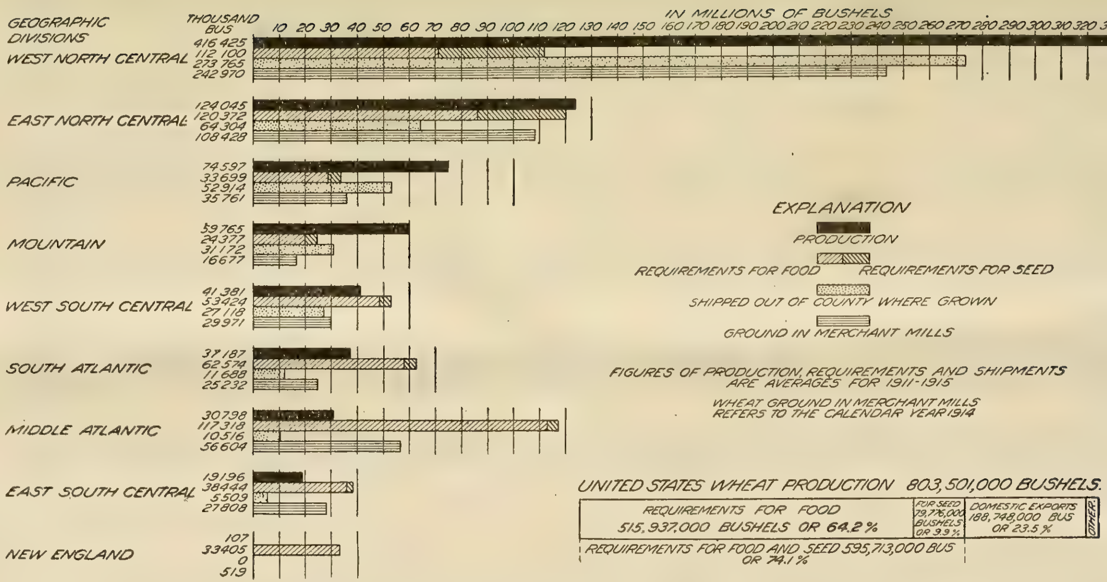

FIG. 1.—Wheat production, requirements, and trade movement, by geographic division.

TABLE I.—*Wheat: Basic elements in geographic price differences:*

| State and geographic division. | Population July 1,1913 (median of 1911–1915). | Production (average 1911–1915). | Wheat ground in merchant mills in 1914.[1] | Shipments out of county where grown (approximate commercial movement). Average 1911-1915. | | Requirements, average, 1911-1915. | |
|---|---|---|---|---|---|---|---|
| | | | | | | For food. | For food and seed. |
| | *Thousands.* | *Thousand bushels.* | *Thousand bushels.* | *Thousand bushels.* | *Per cent of production.* | *Thousand bushels.* | *Thousand bushels.* |
| **United States** | **97,163** | **803,501** | **543,970** | **476,986** | **59.4** | **515,937** | **595,713** |
| New England | 6,865 | 107 | 519 | (2) | (3) | 33,245 | 33,405 |
| Middle Atlantic | 20,570 | 30,798 | 56,604 | 10,516 | 34.1 | 113,223 | 117,318 |
| South Atlantic[5] | 12,764 | 37,187 | 25,232 | 11,688 | 31.4 | 58,448 | 62,574 |
| East North Central | 18,987 | 124,045 | 108,428 | 64,304 | 51.8 | 107,347 | 120,372 |
| West North Central | 12,057 | 416,425 | 242,970 | 273,765 | 65.7 | 71,237 | 112,100 |
| East South Central | 8,690 | 19,196 | 27,808 | 5,509 | 28.7 | 36,151 | 38,444 |
| West South Central | 9,516 | 41,381 | 29,971 | 27,118 | 63.5 | 48,656 | 53,424 |
| Mountain | 2,945 | 59,765 | 16,677 | 31,172 | 52.2 | 18,939 | 24,377 |
| Pacific | 4,769 | 74,597 | 35,761 | 52,914 | 70.9 | 28,691 | 33,699 |
| New England: | | | | | | | |
| Maine | 758 | 80 | 44 | (2) | (3) | 3,562 | 3,574 |
| New Hampshire | 437 | ........ | 402 | (2) | (3) | 2,184 | 2,189 |
| Vermont | 360 | 27 | 15 | (2) | (3) | 1,944 | 1,946 |
| Massachusetts | 3,549 | ........ | 57 | (2) | (3) | 17,744 | 17,838 |
| Rhode Island | 579 | ........ | ........ | (2) | (3) | 2,493 | 2,511 |
| Connecticut | 1,182 | ........ | 1 | (2) | (3) | 5,318 | 5,347 |
| Middle Atlantic: | | | | | | | |
| New York | 9,713 | 7,348 | 36,427 | 2,465 | 33.5 | 52,450 | 53,513 |
| New Jersey | 2,749 | 1,463 | 833 | 412 | 28.2 | 13,747 | 14,028 |
| Pennsylvania | 8,108 | 21,987 | 19,344 | 7,639 | 34.7 | 47,026 | 49,777 |
| South Atlantic: | | | | | | | |
| Delaware | 208 | 1,936 | 735 | 1,112 | 57.4 | 1,040 | 1,271 |
| Maryland | 1,330 | 9,981 | 5,310 | 5,971 | 59.8 | 6,651 | 9,070 |
| Virginia | 2,129 | 11,295 | 10,232 | 3,618 | 32.0 | 9,581 | 11,003 |
| West Virginia | 1,306 | 3,442 | 2,535 | 512 | 14.9 | 7,446 | 7,935 |
| North Carolina | 2,308 | 7,345 | 4,703 | 366 | 5.0 | 10,385 | 11,333 |
| South Carolina | 1,572 | 1,199 | 100 | 18 | 1.5 | 6,760 | 6,950 |
| Georgia | 2,737 | 1,989 | 1,617 | 91 | 4.6 | 10,947 | 11,242 |
| Florida | 826 | ........ | ........ | ........ | ........ | 3,714 | 3,770 |
| East North Central: | | | | | | | |
| Ohio | 4,965 | 31,566 | 27,780 | 14,551 | 46.1 | 31,281 | 34,941 |
| Indiana | 2,761 | 34,950 | 21,200 | 19,116 | 54.7 | 15,737 | 19,479 |
| Illinois | 5,904 | 38,631 | 31,021 | 22,600 | 58.5 | 33,063 | 36,799 |
| Michigan | 2,937 | 15,198 | 14,621 | 7,154 | 47.1 | 14,683 | 16,187 |
| Wisconsin | 2,420 | 3,700 | 13,806 | 883 | 23.9 | 12,583 | 12,966 |
| West North Central: | | | | | | | |
| Minnesota | 2,181 | 59,081 | 124,339 | 35,969 | 60.9 | 15,704 | 21,982 |
| Iowa | 2,222 | 14,098 | 7,118 | 9,159 | 65.0 | 11,779 | 13,215 |
| Missouri | 3,354 | 35,377 | 25,278 | 17,626 | 49.8 | 17,441 | 20,813 |
| North Dakota | 661 | 105,887 | 10,397 | 73,970 | 69.9 | 4,758 | 14,502 |
| South Dakota | 643 | 39,258 | 4,488 | 26,938 | 68.6 | 4,180 | 9,078 |
| Nebraska | 1,233 | 59,844 | 11,405 | 40,126 | 67.1 | 7,152 | 11,884 |
| Kansas | 1,763 | 102,880 | 59,945 | 69,977 | 68.0 | 10,223 | 20,626 |
| East South Central: | | | | | | | |
| Kentucky | 2,336 | 9,813 | 13,114 | 2,892 | 29.5 | 10,513 | 11,650 |
| Tennessee | 2,238 | 8,789 | 14,579 | 2,575 | 29.3 | 9,176 | 10,168 |
| Alabama | 2,239 | 528 | 115 | 27 | 5.1 | 8,954 | 9,077 |
| Mississippi | 1,877 | 66 | ........ | 15 | 22.7 | 7,508 | 7,549 |
| West South Central: | | | | | | | |
| Louisiana | 1,745 | ........ | ........ | ........ | ........ | 7,855 | 7,907 |
| Texas | 4,172 | 13,637 | 18,979 | 7,477 | 54.8 | 22,529 | 24,099 |
| Oklahoma | 1,939 | 26,217 | 9,591 | 19,366 | 73.9 | 11,633 | 14,533 |
| Arkansas | 1,660 | 1,527 | 1,401 | 275 | 18.0 | 6,639 | 6,885 |
| Mountain: | | | | | | | |
| Montana | 419 | 20,900 | 4,143 | 13,025 | 62.3 | 2,515 | 5,284 |
| Wyoming | 163 | 2,366 | 492 | 490 | 20.7 | 1,029 | 1,248 |
| Colorado | 883 | 10,709 | 5,738 | 5,558 | 51.9 | 5,300 | 6,107 |
| New Mexico | 370 | 1,542 | 291 | 304 | 19.7 | 2,924 | 3,061 |
| Arizona | 231 | 879 | 386 | 79 | 9.0 | 1,662 | 1,740 |
| Utah | 405 | 6,601 | 2,525 | 2,221 | 33.6 | 2,469 | 2,951 |
| Nevada | 95 | 1,246 | 193 | 262 | 21.0 | 578 | 676 |
| Idaho | 379 | 15,522 | 2,909 | 9,233 | 59.5 | 2,462 | 3,310 |
| Pacific: | | | | | | | |
| Washington | 1,345 | 49,985 | 17,567 | 37,749 | 75.5 | 8,068 | 10,940 |
| Oregon | 757 | 18,018 | 8,639 | 11,339 | 62.9 | 4,618 | 6,007 |
| California | 2,667 | 6,594 | 9,555 | 3,826 | 58.0 | 16,005 | 16,752 |
| United States | 97,163 | 803,501 | 543,970 | 476,986 | 59.4 | 515,937 | 595,713 |
| Net surplus | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| Exports (domestic wheat) average 1911-1915 | ........ | ........ | ........ | ........ | ........ | ........ | ........ |

---

[1] From census of manufactures, calendar year 1914. Grain ground in custom mills is not included. The figures indicate roughly the trade movement, wheat versus wheat flour.

[2] Less than 500 bushels.

*population, production, requirements, and indicated trade movement.*

| Average surplus or deficiency, 1911–1915. | | Per capita. | | | Distribution in percentages of the United States totals. | | | State and geographic division. |
|---|---|---|---|---|---|---|---|---|
| | | | Requirements. | | | | | |
| Surplus. | Deficiency. | Production. | For food. | For food and seed. | Population. | Production. | Requirements for food and seed. | |
| *Thousand bushels.* | *Thousand bushels.* | *Bushels.* | *Bushels.* | *Bushels.* | *Per cent.* | *Per cent.* | *Per cent.* | |
| **207.788** | ........... | **8.3** | **5.31** | **6.13** | **100** | **100** | **100** | **United States.** |
| ........... | 33,298 | (4) | 4.8 | 4.9 | 7.1 | (3) | 5.6 | New England. |
| ........... | 86,520 | 1.5 | 5.5 | 5.7 | 21.2 | 3.8 | 19.7 | Middle Atlantic. |
| ........... | 25,387 | 2.9 | 4.6 | 4.9 | 13.1 | 4.6 | 10.5 | South Atlantic.[5] |
| 3,673 | ........... | 6.5 | 5.7 | 6.3 | 19.5 | 15.4 | 20.2 | East North Central. |
| 304,325 | ........... | 34.5 | 5.9 | 9.3 | 12.4 | 51.8 | 18.8 | West North Central. |
| ........... | 19,248 | 2.2 | 4.2 | 4.4 | 9.0 | 2.4 | 6.4 | East South Central. |
| ........... | 12,043 | 4.3 | 5.1 | 5.6 | 9.8 | 5.2 | 9.0 | West South Central. |
| 35,388 | ........... | 20.3 | 6.4 | 8.3 | 3.0 | 7.5 | 4.1 | Mountain. |
| 40,898 | ........... | 15.6 | 6.0 | 7.1 | 4.9 | 9.3 | 5.7 | Pacific. |
| | | | | | | | | New England: |
| ........... | 3,494 | .1 | 4.7 | 4.7 | .8 | (3) | .6 | Maine. |
| ........... | 2,189 | (4) | 5.0 | 5.0 | .4 | (3) | .4 | New Hampshire. |
| ........... | 1,919 | .1 | 5.4 | 5.4 | .4 | (3) | .3 | Vermont. |
| ........... | 17,838 | (4) | 5.0 | 5.0 | 3.7 | (3) | 3.0 | Massachusetts. |
| ........... | 2,511 | (4) | 4.3 | 4.3 | .6 | (3) | .4 | Rhode Island. |
| ........... | 5,347 | (4) | 4.5 | 4.5 | 1.2 | (3) | .9 | Connecticut. |
| | | | | | | | | Middle Atlantic: |
| ........... | 46,165 | .8 | 5.4 | 5.5 | 10.0 | .9 | 9.0 | New York. |
| ........... | 12,565 | .5 | 5.0 | 5.1 | 2.8 | .2 | 2.3 | New Jersey. |
| ........... | 27,790 | 2.7 | 5.8 | 6.1 | 8.4 | 2.7 | 8.4 | Pennsylvania. |
| | | | | | | | | South Atlantic: |
| 665 | ........... | 9.3 | 5.0 | 6.1 | .2 | .2 | .2 | Delaware. |
| 911 | ........... | 7.5 | 5.0 | 6.8 | 1.4 | 1.2 | 1.5 | Maryland. |
| 292 | ........... | 5.3 | 4.5 | 5.2 | 2.2 | 1.4 | 1.9 | Virginia. |
| ........... | 4,493 | 2.6 | 5.7 | 6.1 | 1.3 | .4 | 1.3 | West Virginia. |
| ........... | 3,988 | 3.2 | 4.5 | 4.9 | 2.4 | .9 | 1.9 | North Carolina. |
| ........... | 5,751 | .8 | 4.3 | 4.4 | 1.6 | .2 | 1.2 | South Carolina. |
| ........... | 9,253 | .7 | 4.0 | 4.1 | 2.8 | .3 | 1.9 | Georgia. |
| ........... | 3,770 | (4) | 4.5 | 4.6 | .8 | (3) | .6 | Florida. |
| | | | | | | | | East North Central. |
| ........... | 3,375 | 6.4 | 6.3 | 7.0 | 5.1 | 3.9 | 5.8 | Ohio. |
| 15,471 | ........... | 12.7 | 5.7 | 7.1 | 2.8 | 4.3 | 3.3 | Indiana. |
| 1,832 | ........... | 6.5 | 5.6 | 6.2 | 6.1 | 4.8 | 6.2 | Illinois. |
| ........... | 989 | 5.2 | 5.0 | 5.5 | 3.0 | 1.9 | 2.7 | Michigan. |
| ........... | 9,266 | 1.5 | 5.2 | 5.4 | 2.5 | .5 | 2.2 | Wisconsin. |
| | | | | | | | | West North Central: |
| 37,099 | ........... | 27.1 | 7.2 | 10.1 | 2.2 | 7.4 | 3.7 | Minnesota. |
| 883 | ........... | 6.3 | 5.3 | 5.9 | 2.3 | 1.8 | 2.2 | Iowa. |
| 14,564 | ........... | 10.5 | 5.2 | 6.2 | 3.4 | 4.4 | 3.5 | Missouri. |
| 91,385 | ........... | 160.2 | 7.2 | 21.9 | .7 | 13.1 | 2.4 | North Dakota. |
| 30,180 | ........... | 61.1 | 6.5 | 14.1 | .7 | 4.9 | 1.5 | South Dakota. |
| 47,960 | ........... | 48.5 | 5.8 | 9.6 | 1.3 | 7.4 | 2.0 | Nebraska. |
| 82,254 | ........... | 58.4 | 5.8 | 11.7 | 1.8 | 12.8 | 3.5 | Kansas. |
| | | | | | | | | East South Central: |
| ........... | 1,837 | 4.2 | 4.5 | 5.0 | 2.4 | 1.2 | 1.9 | Kentucky. |
| ........... | 1,379 | 3.9 | 4.1 | 4.5 | 2.3 | 1.1 | 1.7 | Tennessee. |
| ........... | 8,549 | .2 | 4.0 | 4.1 | 2.3 | .1 | 1.5 | Alabama. |
| ........... | 7,483 | (4) | 4.0 | 4.0 | 2.0 | (8) | 1.3 | Mississippi. |
| | | | | | | | | West South Central: |
| ........... | 7,907 | (4) | 4.5 | 4.5 | 1.8 | (3) | 1.3 | Louisiana. |
| ........... | 10,462 | 3.3 | 5.4 | 5.8 | 4.3 | 1.7 | 4.1 | Texas. |
| 11,684 | ........... | 13.5 | 6.0 | 7.5 | 2.0 | 3.3 | 2.4 | Oklahoma. |
| ........... | 5,358 | .9 | 4.0 | 4.1 | 1.7 | .2 | 1.2 | Arkansas. |
| | | | | | | | | Mountain: |
| 15,616 | ........... | 49.9 | 6.0 | 12.6 | .4 | 2.6 | .9 | Montana. |
| 1,118 | ........... | 14.5 | 6.3 | 7.6 | .2 | 1.9 | .2 | Wyoming. |
| 4,602 | ........... | 12.1 | 6.0 | 6.9 | .9 | .3 | 1.0 | Colorado. |
| ........... | 1,519 | 4.2 | 7.9 | 8.3 | .4 | 1.4 | .5 | New Mexico. |
| ........... | 861 | 3.8 | 7.2 | 7.5 | .2 | .2 | .3 | Arizona. |
| 3,650 | ........... | 16.3 | 6.1 | 7.3 | .4 | .1 | .5 | Utah. |
| 570 | ........... | 13.1 | 6.1 | 7.1 | .1 | .8 | .1 | Nevada. |
| 12,212 | ........... | 41.0 | 6.5 | 8.7 | .4 | .2 | .6 | Idaho. |
| | | | | | | | | Pacific: |
| 39,045 | ........... | 37.2 | 6.0 | 8.1 | 1.4 | 6.2 | 1.9 | Washington. |
| 12,011 | ........... | 23.8 | 6.1 | 7.9 | .8 | 2.2 | 1.0 | Oregon. |
| ........... | 10,158 | 2.5 | 6.0 | 6.3 | 2.7 | .9 | 2.8 | California. |
| [6]424,004 | [6]216,216 | 8.3 | 5.31 | 6.13 | 100 | 100 | 100 | United States. |
| 207,788 | ........... | ........... | ........... | ........... | ........... | ........... | ........... | Net surplus. |
| 188,748 | ........... | ........... | ........... | ........... | ........... | ........... | ........... | Exp'ts (domestic wheat) average 1911-1915. |

[3] Less than one-tenth of 1 per cent.
[4] Less than one-tenth of 1 bushel.
[5] Includes the District of Columbia.
[6] Gross surplus and deficiency.

New England States.—This section is almost completely dependent for its wheat supplies upon shipments from the West. The small quantity of wheat ground indicates that practically the entire deficit is supplied in the form of wheat flour. The movement to this division consists not only of some 33 million bushels required for its consumption, but includes also an additional 25 million bushels of wheat exported from its seaports, less than 3 million bushels more in the form of wheat flour, and a few million bushels of Canadian transit wheat.

Middle Atlantic States.—The dominating influence of the three States in this section is shown by the fact that half the gross surplus of the country is drawn here for consumption and export, as well as millions of bushels of Canadian wheat. The section contains the largest population but produces scarcely one-fourth of its requirements for food and seed. Only a third of its production enters into the shipments out of counties where grown, indicating local consumption for seed, in custom mills, etc. Its flour mills grind about twice the quantity of wheat produced. Shipments to this group of States, supplying a deficit of 117 million bushels, are augmented by 50 million bushels in the form of wheat flour and 65 million bushels of wheat for export, chiefly via New York; also by nearly 50 million bushels of Canadian wheat, shipped in bond.

South Atlantic States.—The requirements are about double the local production. Virginia and Maryland produce about 60 per cent of the wheat in the eight States of this section and bring up the average. The small fraction of the crop shipped out of counties where grown suggests local consumption for seed and in custom flour mills, no data for the latter being available. Wheat ground in merchant mills is less than production. The two northern ports in this section, Baltimore and Newport News, draw in addition about 20 million bushels for export.

East South Central States.—The two States of Kentucky and Tennessee produce practically all of the wheat in this division, and also mill nearly all of the product that enters into merchant mills. As a section, the figures show production equal to half of the requirements; the small percentage of shipments out of counties where grown indicates local consumption and use in custom mills. The wheat flow to this section is largely in the form of wheat flour. Very little wheat is exported from its ports.

West South Central States.—Oklahoma produces nearly 60 per cent of the crop of this section, and the small percentage which is ground in Oklahoma merchant mills indicates its shipment unmilled. The section considered in its entirety raises about 80 per cent of its requirements for food and seed. The trade current to this group supplies a net deficit of some 12 million bushels and includes some 35 million bushels of wheat and 7 million bushels equivalent of wheat flour, moving to New Orleans and Galveston for export. The export movement through the Gulf ports is increasing rapidly.

East North Central States.—The figures for Indiana in the production column bring up production to about an equality with the requirements. Wisconsin grinds several times its production, the other States less than their production.

West North Central States.—This is the great surplus wheat area, growing 51.8 per cent of the national wheat, or 416 out of 803 million bushels, with only 12 per cent of the national population and 17 per cent of the land area—or less than four times the requirements for food and seed. North Dakota (160 bushels per capita) and Kansas (58 bushels per capita) contribute about 60 per cent of the wheat grown in the seven States of this section, which supplies not only the greater part of the domestic deficiencies east of the Rockies, but also most of the export wheat. Deducting the Pacific wheat, which normally enters into a distinct trade westward, this division furnishes nearly 80 per cent of the gross surplus of the United States. The one State of Minnesota grinds more than half of the wheat milled in this area—several times the State production. The aggregate figures suggest an export movement of wheat and wheat flour in about equal proportions.

Mountain States.—The per capita production in these States is very high; only in Montana and Idaho, however, does the local production attain relative importance. The southern part of the division grows insufficient wheat for its needs. Population and wheat production are widely scattered, and the region is still in a developmental state, the census of 1910 reporting only 2 per cent of its area as being improved. Only a small proportion of the export wheat is milled, part moving westward and the major portion finding its way to markets east of the Rockies.

Pacific States.—The bulk of the Pacific wheat production is concentrated in eastern Washington and northeastern Oregon, as will be seen from Map 2. California's production has declined to a fraction of the State's requirements. The surplus wheat from eastern Washington and Oregon, with some from adjoining Mountain States, supplies deficiencies in this section, the major part seeking a market in Europe and the Orient. Pacific mills grind less than half the local crop, surplus wheat being shipped, as a rule, unmilled.

## SECTIONAL PRICE RATIOS SHIFTING.

Price maps based upon averages for five years, 1910–1914, to determine normal conditions.

Geographic price differences change slowly with economic transformations.

Spasmodic deviations from usual price relationships due to unusual local conditions.

Application to specific purposes of the maps and local price alignments to which attention is now addressed is in a measure contingent upon an understanding of the data upon which they are based. Emphasis is laid upon the fact that the price zones as mapped and given in tabular form within the appendix represent normal conditions determined by a five-year average (1910–1914), showing regular and definable tendencies, both general and local.

These geographic price differences are not fixed; they are slowly changing with other economic conditions. This phase is more fully treated on pages 24–27, wherein are shown the steadily diminishing price differences in wheat between exporting western and importing eastern sections, coincident with the decline in transportation charges, attended also by a decreasing wheat production in the East. Similarly, marked changes occurred in Mountain States disadvantageously situated as to markets, in which formerly—when deficient in wheat supplies—very high prices prevailed, and where now there are low prices, since these States have eventually come to produce a surplus of wheat.

Subordinate to the general price movement, temporary deviations from the usual price relationships are found. A local crop failure may occur, or the crop may be of poor quality, and a region, usually exporting, must bring in supplies. The Kansas corn crop was practically a failure in 1913, because of a severe drought; large quantities of corn had to be brought in for local needs. As a result, the farm price ratios were disrupted, the Kansas farm price becoming considerably higher than that of adjoining States, even exceeding that of Pennsylvania, although usually about 10 cents per bushel less. (See fig. 2.)

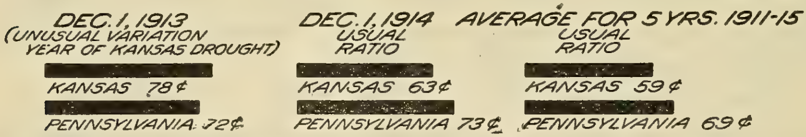

FIG. 2.—Usual and unusual farm-price ratio per bushel of corn, Kansas and Pennsylvania.

A very striking illustration of deviation from the usual sectional farm price ratio is afforded by the situation in the Pacific Coast States in 1916. The Pacific wheat surplus could not follow its usual course to Europe because of the scarcity of ocean tonnage, hence it was shipped by rail to eastern markets. The ordinary price progression of the far western States gives higher prices as the Pacific ports are reached; Idaho and Montana, at a geographical disadvantage to eastern and Pacific markets, represent areas of lowest price. Because of the eastward rail movement in 1916 the geographic situation was reversed, and Montana wheat brought higher farm prices; similarly, the price disparity between Pacific and eastern surpluses was widened, the higher rail freight being substituted for cheaper ocean rates. (See fig. 3.)

Notwithstanding the apparently bewildering lack of regularity in the individual price quotations, the application of statistical method to the great mass of numerical data which have been made the basis of the maps, and the use of a 5-cent unit to overcome minor differences such as are due to grades, develop a sustained regularity in the geographic price comparisons. The regional differences in farm prices reflect current economic conditions; they are changing slowly with the development of the country; subordinate to this general movement spasmodic deviations arise.

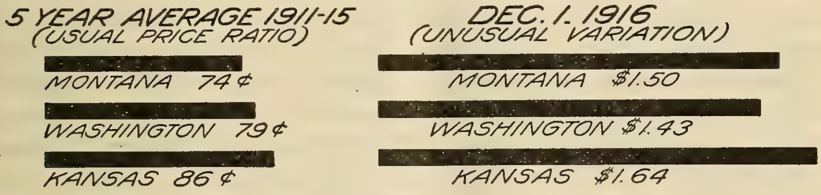

**Fig. 3.**—Deviation from usual farm-price ratio, per bushel of wheat, Montana, Washington, and Kansas.

## DETAIL FARM PRICE MAP AND LOCAL PRICE CONDITIONS.

Stability of farm prices where wheat traffic is in great volume, across Northern States.

Mountainous regions and areas disadvantageously placed as to transportation facilities; irregularity of prices therein; surplus wheat areas show lowest prices; deficient areas highest prices.

Map 3 is designed to show local variations in the general price zones through the use of a 5-cent unit.

Previous paragraphs have treated of the general direction of the price progressions. An examination of the price maps will disclose many small areas in which farm prices are higher or lower than in the surrounding territory. Greatest stability and slowest rate of increase attend the direction wherein grain traffic is in largest volume—across the Mississippi, through Illinois and Ohio, toward the North Atlantic ports. Similarly, in the Pacific northwest, price levels rise steadily toward the seaboard. On the other hand, prices paid to farmers reach higher and more irregular levels within the arid interior and southwest, sections deficient in wheat production, with scanty population, having no points of large concentration, and drawing wheat in relatively small quantities. High figures usually obtain in regions of little or no wheat production. It will be noted that in importing areas—as in the Appalachian region—not well served by transportation facilities, prices are high and irregular. Surplus areas not favorably situated as to transportation and markets show lowest farm prices, notwithstanding proximity to areas of higher prices, as will be seen in parts of Idaho and Colorado.

### EFFECT OF MARKETS ON LOCAL FARM PRICE VARIATIONS.

Price elevations around wheat markets; influence of markets on farm price gradations; large wheat consumption of grain centers.

Wheat receipts, shipments, exports, and flour production at chief markets in relation to total commercial movement.

Consideration of price zones in connection with the great wheat markets located on Map 3 will indicate the relationship between grain centers and farm prices. In a report of the Industrial Commission[1] the grain territory tributary to the leading markets was mapped. In Map 4 this map is reproduced with the price zones of Map 3 superimposed. The effect on farm prices of proximity to the great wheat markets is apparent. On the north farm prices rise to a maximum around Minneapolis; slightly farther south they graduate upward toward Chicago and Milwaukee. Likewise, subordinate to the general price direction, higher levels obtain around Kansas City, St. Louis, San Francisco, and other important markets. Reports indicate that sections deficient in supply, east and south, draw the greater part of their wheat from these ''primary markets''—the points in which wheat is concentrated in the first stages of its movement. Each of the markets has a territory from which it usually derives its wheat, freight rates being the determining factor, and farm prices tend to graduate in proportion thereto. A difference of a fraction of a cent in freight, elevating charges, etc., will alter the course of the wheat traffic.

The great wheat markets are important, not only as commercial centers and points of wheat concentration, but also as eventually consuming a large part of the domestic wheat. A score of the largest markets represent about one-fifth of the total consumption of the country. It is estimated that the metropolitan district of New York consumes 30 million bushels annually—equal to the entire production of the Middle Atlantic States or the average surplus of South Dakota. A few of the western primary markets are simply reshipping points, with little local consumption.

In Table II (p. 15) data have been assembled explanatory of the importance of the markets on geographic phases of farm prices of wheat. It will be noted that 13 primary markets receive some 481 million bushels of wheat and wheat flour. Comparing with the figures in Table I, the North Central States (in which these markets are located) grow 540 million bushels, with shipments out of counties where grown aggregating 337 million. Allowing for considerable duplication and inaccuracies in reports of receipts, the degree of concentration is evident. Exclusive of the Canadian shipments, Buffalo alone handles somewhat less than one-fifth of the total wheat production of the country and the major part of the wheat destined for the east and northeast. In six Atlantic and Gulf seaports, receipts total one-half of the wheat east of the Rockies entering into commercial channels. To this should be added about 60 million bushels of Canadian wheat and wheat flour shipped in bond via Atlantic ports. A dozen cities around the Great Lakes mill one-fourth of the total wheat flour.

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[1] Report of the Industrial Commission, Vol. VI.

TABLE II.—*Leading wheat markets: Receipts, shipments, and flour production, in five-year averages (1911–1915).*

[Taken from unofficial returns. Figures for some markets are incomplete; allowance must also be made for duplication, intermediate markets crediting themselves with through shipments, etc.]

**(In figure columns 000 omitted.)**

| Principal wheat markets. | Wheat. | | | Wheat flour. | | | Wheat and wheat flour.[1] | |
|---|---|---|---|---|---|---|---|---|
| | Receipts. | Disposition. | | Receipts. | Production. | Shipments. | Receipts. | Shipments. |
| | | Milled.[1] | Reshipped. | | | | | |
| EASTERN AND SOUTHERN SHIPMENTS. | | | | | | | | |
| Primary markets: | *Bushels.* | *Bushels.* | *Bushels.* | *Barrels.* | *Barrels.* | *Barrels.* | *Bushels.* | *Bushels.* |
| Minneapolis | 116,056 | 77,724 | 34,445 | 665 | 17,272 | 17,776 | 119,049 | 114,437 |
| Duluth | 65,453 | 4,851 | 60,684 | 5,274 | 1,078 | 6,356 | 89,186 | 89,284 |
| (Canadian shipments in bond)[2] | (6,828) | ........ | (6,676) | * | ........ | * | (6,828) | (6,676) |
| Chicago | 58,680 | 4,694 | 49,222 | 8,394 | 1,043 | 6,671 | 96,453 | 79,243 |
| Kansas City | 46,549 | 10,292 | 34,528 | 193 | 2,287 | 1,929 | 47,417 | 43,208 |
| St. Louis | 29,539 | 5,643 | 22,463 | 3,290 | 1,254 | 3,806 | 44,344 | 39,588 |
| Milwaukee | 8,892 | 3,812 | 4,861 | 3,320 | 847 | 3,641 | 23,832 | 21,245 |
| Omaha | 16,964 | * | 11,079 | * | * | * | 16,964 | 11,079 |
| Cincinnati | 4,433 | * | 3,185 | 1,501 | * | 1,095 | 11,187 | 8,113 |
| Toledo | 6,856 | 6,278 | 3,925 | * | 1,395 | * | 6,856 | 3,925 |
| Cleveland | 2,939 | 1,476 | 961 | 696 | 328 | 168 | 6,071 | 1,717 |
| Detroit | 2,235 | 3,298 | 1,066 | 346 | 733 | 396 | 3,792 | 2,848 |
| Indianapolis | 3,194 | 2,151 | 1,140 | * | 478 | * | 3,194 | 1,140 |
| Peoria | 2,390 | * | 2,269 | 2,363 | * | 2,900 | 13,023 | 15,319 |
| Total | 364,180 | 120,219 | 229,828 | 26,042 | 26,715 | 44,738 | 481,368 | 431,146 |
| Other markets: | | | | | | | | |
| Buffalo— | | | | | | | | |
| Domestic wheat | [3]111,392 | 24,314 | * | [3]8,330 | 5,403 | * | 148,877 | * |
| Canadian shipments in bond | 46,497 | ........ | ........ | ........ | ........ | ........ | 46,497 | ........ |
| New York— | | | | | | | | |
| Domestic wheat | 55,444 | 4,842 | [4]48,120 | 10,102 | 1,076 | [4]4,929 | 100,903 | [4]70,300 |
| Canadian shipments in bond | 24,000 | ........ | ........ | 972 | ........ | ........ | 28,374 | ........ |
| Philadelphia— | | | | | | | | |
| Domestic wheat | 22,694 | 2,826 | [4]19,445 | 2,385 | 628 | [4]1,056 | 33,426 | [4]24,197 |
| Canadian shipments in bond | 8,820 | ........ | ........ | 197 | ........ | ........ | 9,706 | ........ |
| Baltimore— | | | | | | | | |
| Domestic wheat | 21,752 | * | [4]19,950 | 1,920 | * | [4]930 | 30,392 | [4]24,135 |
| Canadian shipments in bond | 8,040 | ........ | ........ | 54 | ........ | ........ | 8,283 | ........ |
| Boston— | | | | | | | | |
| Domestic wheat | 14,273 | * | [4]14,391 | 1,961 | * | [4]668 | 23,097 | [4]17,397 |
| Canadian shipments in bond | 10,490 | ........ | ........ | 284 | ........ | ........ | 11,768 | ........ |
| New Orleans | 18,005 | * | [4]16,886 | 2,087 | * | [4]1,362 | 27,397 | [4]23,015 |
| Newport News and Norfolk | ........ | ........ | [4]3,159 | ........ | ........ | [4]218 | ........ | [4]4,140 |
| Galveston | 19,818 | * | 18,107 | ........ | * | 297 | 19,818 | 19,443 |

* No reports.

[1] Flour converted to wheat at 4½ bushels per barrel.

[2] Canadian shipments in bond are in addition to other figures.

[3] Lake receipts only.

[4] Exports.

TABLE II.—*Leading wheat markets: Receipts, shipments, and flour production, in five-year averages (1911–1915)*—Continued.

| Principal wheat markets. | Wheat. | | | Wheat flour. | | | Wheat and wheat flour. | |
|---|---|---|---|---|---|---|---|---|
| | Receipts. | Disposition. | | Receipts. | Production. | Shipments. | Receipts. | Shipments. |
| | | Milled. | Reshipped. | | | | | |
| EASTERN AND SOUTHERN SHIPMENTS—continued. | | | | | | | | |
| Other markets—Continued. | | | | | | | | |
| Portland, Me.— | *Bushels.* | *Bushels.* | *Bushels.* | *Barrels.* | *Barrels.* | *Barrels.* | *Bushels.* | *Bushels.* |
| Domestic wheat | * | | [1] 7,887 | | | [1] 143 | | [1] 8,531 |
| Canadian shipments in bond | 7,074 | * | * | 197 | * | * | 7,960 | |
| Mobile | | | [1] 31 | | | [1] 533 | | [1] 2,429 |
| Louisville | 5,035 | [2] 5,670 | 135 | [2] 144 | [2] 1,260 | [2] 1,108 | 5,683 | 5,121 |
| Denver | 3,316 | | | | | | 3,316 | |
| PACIFIC COAST WHEAT. | | | | | | | | |
| Seattle [3] | 9,349 | 5,020 | 4,678 | 548 | 1,049 | 1,243 | 11,815 | 10,271 |
| Tacoma [3] | 11,902 | 6,044 | 4,600 | * | 1,343 | 1,496 | 11,902 | 11,332 |
| San Francisco | 6,215 | * | [1] 248 | 1,260 | | [1] 210 | 11,885 | [1] 1,193 |
| Portland [2] | 17,419 | | 13,853 | 496 | | 997 | 19,651 | 18,339 |
| Spokane [2] | 1,334 | | | | | | 1,334 | |

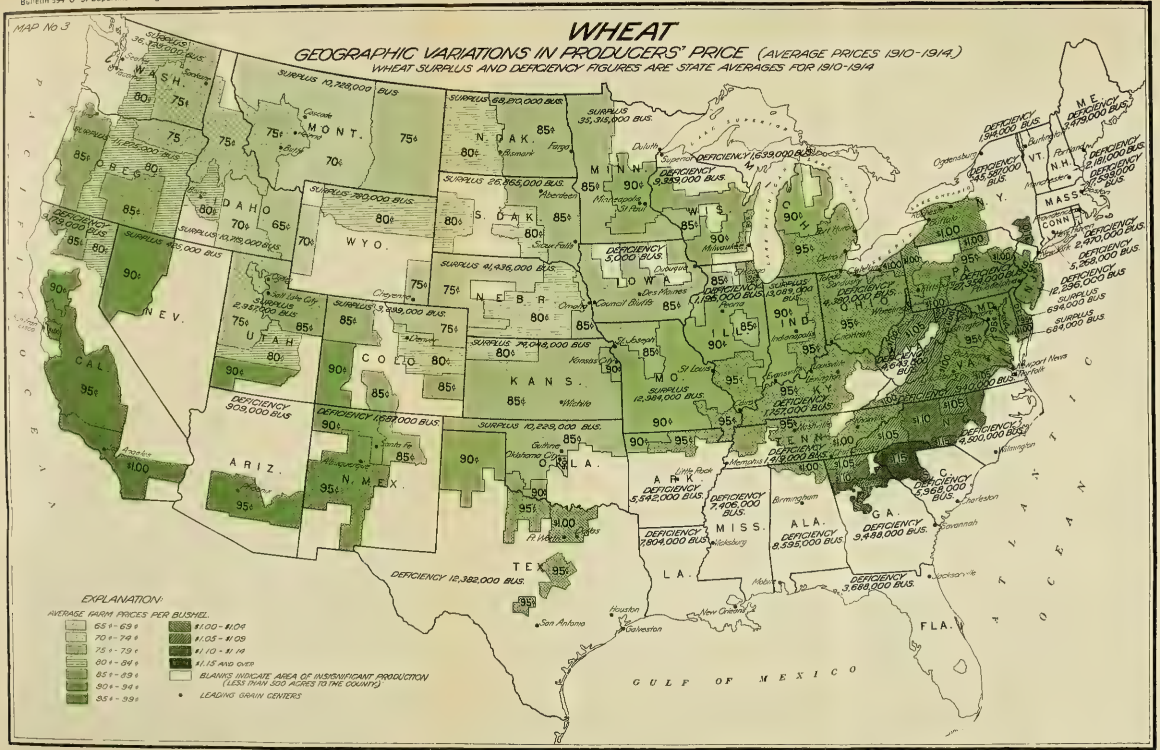
* No reports. [1] Exports. [2] Figures for 1915 only. [3] Averages for 1912–1915.

## FREIGHT RATES.

Most important element in price disparities represented by transportation costs.
Export prices of wheat influence farm prices.
Wheat takes a special rate; complicated rate structure; effect of reshipping, distance, and milling-in-transit rates on farm prices.

The national wheat surplus, that is, the exports, constituted during the past 10 years, from 11 to 37 per cent of the production. It is the price received for this surplus which, broadly stated, tends to regulate the farm prices of the entire crop. Preceding maps have outlined the gradual elevation in the farm prices of wheat toward the seaboard, with minor increases culminating as each of the great markets is reached. In this progression a preponderant factor is cost of transportation, other items of distributive expense being usually in fractions of 1 cent per bushel. Evidently a definite proportion tends to exist between prices prevailing at the different markets, domestic and foreign, measured principally by differences in freight. In foreign markets tariffs often supervene to disturb this relationship. Prices paid to farmers for wheat tend to graduate from the markets in proportion to freight charges thereto. In surplus wheat areas farm prices decrease steadily with distance from markets, while in areas raising insufficient wheat for home needs prices are apt to be higher than they are near large markets, the increase in price being affected by freight rates from the nearest surplus points.

(NOTE—The difference in price between any two regions may be regarded as practically stable, regardless of changes in the prices themselves. This map serves as an index of geographic variation in farm prices)



MAP No 3

# WHEAT

## GEOGRAPHIC VARIATIONS IN PRODUCERS' PRICE (AVERAGE PRICES 1910-1914)

WHEAT SURPLUS AND DEFICIENCY FIGURES ARE STATE AVERAGES FOR 1910-1914

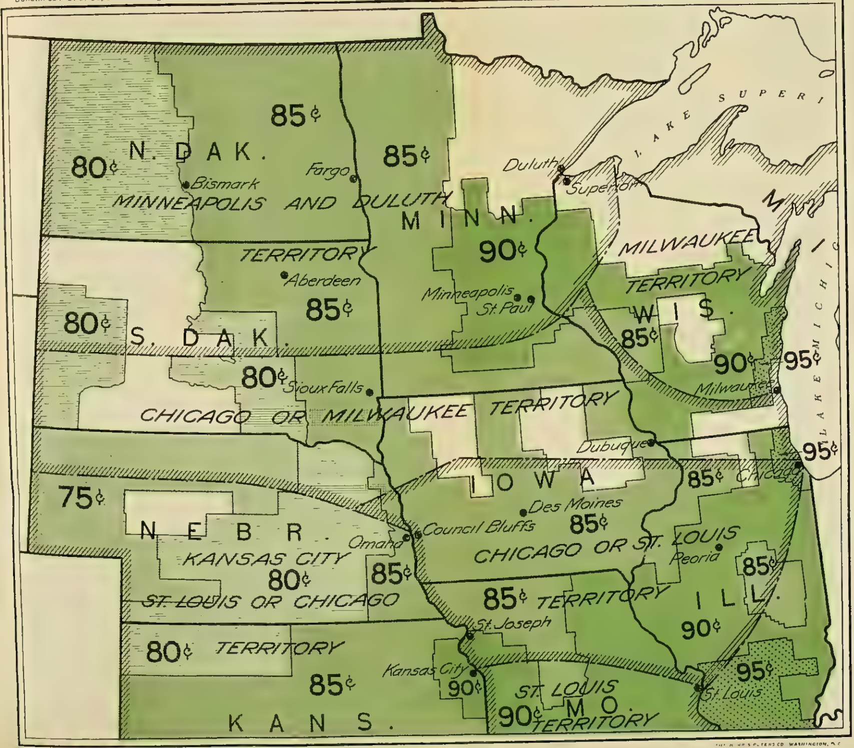
THE NORRIS PETERS CO., WASHINGTON, D. C.

## EFFECT ON FARM PRICES OF WHEAT OF NEARNESS TO OR REMOTENESS FROM GRAIN MARKETS.

(Figures and color areas represent farm prices of wheat as given on Map 3. The territory from which each market or group of markets receives most of its wheat is outlined on the map by an etched border.

Bulletin 594 U. S. Department of Agriculture.

MAP 4.



▨ 95¢ ▨ 90¢ ▨ 85¢ ▨ 80¢ ▨ 75¢

GEOGRAPHY OF WHEAT PRICES.

For the purpose of presenting concretely the effect of transportation charges on regional differences in prices paid to farmers, such charges may here be divided into the two general classes of export (or ocean) and domestic freights. Ocean freights fluctuate greatly, but taking the year 1913 as one in which normal conditions prevailed, the following illustration will serve:

*Average ocean freights per bushel of wheat, 1913.*

| From— | To Liverpool, England. |
|---|---|
| | *Cents.* |
| New York | 5.6 |
| Baltimore | 6.6 |
| New Orleans | 8.8 |
| Columbia River and Puget Sound | 21.0 |

*Export wheat, all rail, carload lots, 1913, per bushel.*

| From— | To— | Cents. |
|---|---|---|
| Chicago | New York | 10 |
| Kansas City | do | 15 |
| Do | New Orleans | 11.1 |

Thus the normal difference of about 5 cents per bushel in favor of Chicago, in the total transportation costs to Liverpool, as compared with the rate from Kansas City, represents also the disparity in the farm prices of adjoining territories, as will be seen by reference to map 3.

Similarly, the Pacific Ocean rates quoted above, although considerably cheaper than rail freights eastward, are yet nearly four times the ocean freight from New York. This higher transportation cost to European markets is an important factor in the lower prices received by Pacific wheat growers.

The line of cleavage between Pacific and eastern markets may be noted in the following rates from the area of lowest wheat prices:

*Approximate transportation costs from Blackfoot, Idaho, to Liverpool, England (1913), per bushel of wheat.*

| Via Pacific: | *Cents.* | Via Atlantic: | *Cents.* |
|---|---|---|---|
| By rail to Seattle or Tacoma | 24 | By rail to New York | 39.2 |
| Ocean freight to Liverpool | 21 | New York to Liverpool | 5.6 |
| Total | 45 | Total | 44.8 |

Transportation costs from Kansas City to Liverpool (1913) were about 20 cents per bushel. This difference of 25 cents, compared with the above, is reflected in the farm prices in surrounding areas—65 cents as against 90 cents.

In the internal commerce, wheat takes a special or commodity rate, with a complicated rate structure adapted to the characteristics of its commercial movement. The freight rates on grain are constantly changing, but their main features are constant; also the elaborate rate structure which accounts for many geographic price differences. Only a brief statement of a few phases of wheat rates, in so far as they relate to the geography of farm prices, is possible here.

In connection with large areas of equal price in the wheat belt, it may be noted that although length of haul is an important element, the freight rates are not directly in proportion thereto. The following example is pertinent:

*Distance rates between points in Kansas and Oklahoma, Atchison, Topeka & Santa Fe Railway.*

[Rates per bushel of wheat (carload lots) in 1916.]

| | |
|---|---|
| 10–14 miles | $0.03 |
| 96–100 miles | .069 |
| 196–200 miles | .093 |

Thus 20 times the distance takes only 3 times the 10-mile rate. The wheat rate from Chicago is the same to all points in New England; the rate to Baltimore applies also to Richmond and Newport News. The freight rate from the trans-Mississippi wheat belt to our southeastern States usually is higher than to England. Export wheat moves to the seaboard at lower freight rates than does wheat intended for domestic consumption.

The natural tendency toward wheat concentration in the great commercial centers is enhanced by their use as rate-basing points, as well as by the reshipping and milling-in-transit rates. Flour usually takes a higher rate than wheat, but by the milling-in-transit privilege wheat may be stopped at some point en route, milled, and the product moved on again at the original rate charged for a through wheat shipment[1] to the eventual destination, instead of paying the local rate to the milling point and local flour rate to the destination. By means of the reshipping rate wheat may be moved into a primary market, say Chicago, and shipped on again, taking the through rate to the final destination instead of the sum of the local rates.

*All-rail freight rates per bushel of wheat, in 1916 (carload lots).*

| From— | | | To Buffalo, Wheeling, Pittsburgh. | To Baltimore, Washington, Rochester, Newport News. | To New York. | To Boston, Portland, and New England points. |
|---|---|---|---|---|---|---|
| Chicago | For domestic use | Local rate | $0.09 | $0.113 | $0.131 | $0.143 |
| | | **Reshipping rate** | **.06** | **.083** | **.101** | **.113** |
| | For export | Local rate | | .10 | .108 | .108 |
| | | Reshipping rate | | .069 | .078 | .078 |
| Toledo or Delaware, Ohio, **through local rate** | | | **.06** | **.08** | **.098** | **.11** |

Thus the local rate applying on wheat originating at or near Delaware, Ohio, or Toledo is about the same as the reshipping rate from Chicago, which applies to practically all shipments from that point. Reference to the maps will indicate the effect of this rate, as well as of the low rates via the Great Lakes, in the equality of farm prices near Chicago with those farther east and much nearer the seaports.

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[1] In some cases railroads apply the through flour rate to such traffic.

Still another complication is the difference in freight rates between carload and less-than-carload lots, which would particularly affect regions in which wheat traffic is small.

### OTHER PRICE FACTORS.

Distinct use made of certain varieties of wheat, with individual price conditions.
Local value of mill by-products; discriminatory effect of tariffs and freights on flour production.

Another factor affecting farm price is the demand for one kind of wheat compared with the demand for another kind. Thus durum or macaroni wheat meets a distinct demand in export and domestic trade; the hard spring and winter wheat is highly esteemed for bread making, and the softer wheats are considered better adapted for use in pastries. A general practice exists of bringing up the gluten content of the softer wheats by an admixture of the harder varieties. For example, notwithstanding the general easterly and southerly movement of hard Kansas wheat, some of it is shipped westward to Denver, where it is blended with the softer irrigated wheats.

The economic advantages of milling wheat close to the sources of raw material are offset in part by higher freights on flour, in part by local values of mill by-products, and by characteristics of the reshipping and milling-in-transit freight rates. Then, too, foreign tariffs frequently discriminate against flour imports, up to the point of absolute prohibition. It is usually considered that, on an average, 4½ bushels of No. 2 hard wheat produce one barrel of flour (196 pounds) and 70 pounds of feed, with 4 pounds of loss.

In concluding it may be added that, manifestly, from the very nature of the case, only the broad general conditions applying to the regional price differences can be entered into here. No single set of conditions alone determines a price, but each more or less determinable factor is influenced by other elements. Hence the treatment of causes has been intended as merely indicative and concerned primarily with the mention of some of the more noteworthy ones. In a publication of this character it has seemed best merely to set forth facts and conditions, with the avoidance, so far as possible, of discussions of economic theory.

### SUMMARY: PRICE VARIATIONS AND ATTENDANT CONDITIONS.

In the selection of crops for which climate and soil are fitted, geographic differences in producers' prices constitute a potent factor. Isothermal lines indicate zones of like temperature; in a similar manner farm prices group themselves geographically into zones, responding to economic conditions attending the transit of wheat from areas of supply to those of demand. These zones vary with each product.

Sectional price ratios are not fixed; dynamic in character, they shift slowly with general economic changes. Moreover, temporary upheavals frequently occur in price relationships, in response to changes in local and general price factors.

The lowest farm prices appear in the surplus areas of Idaho and Montana, with small consuming populations and most disadvantageously situated as to foreign markets, having a short rail but a long ocean haul westward, a long rail and short ocean haul eastward. From this pivotal area wheat prices graduate upward in every direction, following closely the movement of wheat toward the areas of deficient production. Toward the Pacific they increase to the west and south; toward the Atlantic the price graduations flow to the east and south, with maximum prices in the southeast.

Subordinate to the general price current, localities with higher or lower price levels than those in the surrounding territory may be found, responding to peculiarities of the commercial wheat movement. Comparative stability and small local differences in prices appear in the great wheat-producing sections, which have great volume of wheat traffic, competitive primary markets, and elaborate freight adjustments. Where wheat moves in smaller volume, greater price irregularity as well as higher prices obtain. In the mountainous areas raising insufficient wheat, as, for instance, in the Appalachian region, farm prices are higher; on the other hand, western exporting areas unfavorably situated as to transportation show lower prices, notwithstanding geographical proximity to regions of higher price.

A large part of the commercial wheat appears in a limited number of markets, with highly organized distributive systems. Each has a territory from which it ordinarily receives its supplies.

The largest single element in the regional price disparities is represented by freight rates. Though subject to change, in their main features they are constant in their influence on price conditions.

## FARM PRICES CORRELATED WITH COSTS OF PRODUCTION, BY STATES AND SECTIONS.

Yields to the acre and costs per acre of wheat qualifying sectional price advantages.

Factors which enable areas with lowest priced wheat to show greatest net return.

A distinction should, of course, be drawn between gross price and net price to producers. Two qualifying factors appear in yields to the acre and costs per acre. Price and cost elements have been assembled in Table III (p. 22).

Costs of producing wheat are on an acreage basis; high yields depress and low yields increase costs per bushel. Figure 4 has been added to throw into relief the proportionate significance of these factors. It will be seen that areas of high price show minimum net returns, higher prices per bushel being offset either by high acreage costs or such relatively low yields to the acre as to make the per bushel cost high. Varying land rental or interest charges, as well as costs of commercial fertilizers, are also shown.

In the South Atlantic States we see the highest price per bushel but lowest yields to the acre, hence highest proportionate cost per bushel, reducing returns per acre (see lower chart) to a point only slightly over costs. The New England and Middle Atlantic States, with high prices and high yields, show large returns per acre, offset by highest costs to the acre (in which high fertilizer and land-rental charges enter). On the other hand, the Mountain and Pacific States, with low prices per bushel but high yields, show in the lower chart high returns per acre and lowest costs.

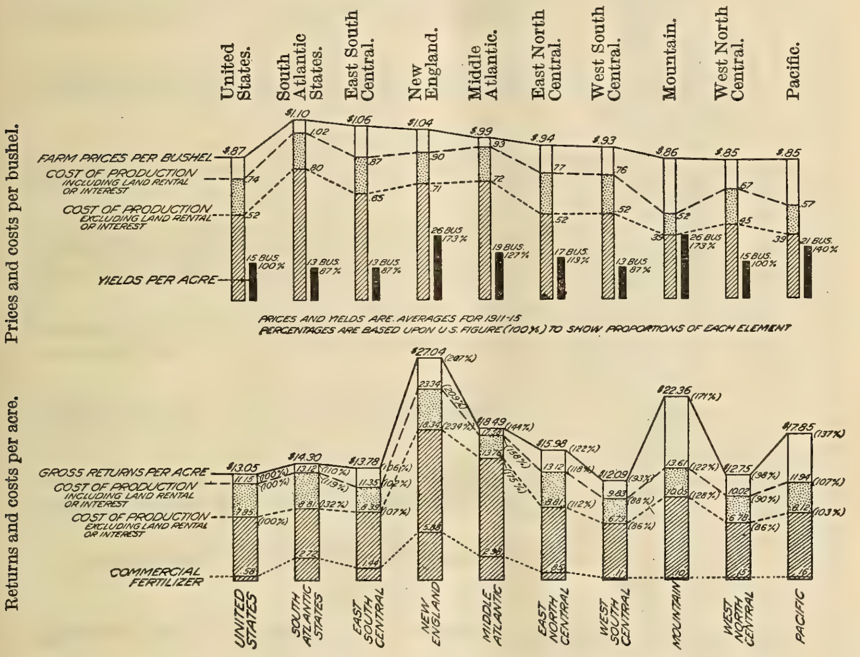

FIG. 4.—Wheat: Farm prices, yields, and costs of production, by geographic divisions. (For details, see Table III, p. 22.)

Details follow in Table III. Relationships can best be seen in the percentages, basing the United States figure as 100 per cent. Thus we see in Montana, price per bushel is 85 per cent (compared with the United States as 100), but average yield is 167 per cent, and correlating the two in value per acre, 142 per cent; cost of production, excluding land rental or interest, 117 per cent; finally, ratio of returns to cost 201 per cent.

TABLE III.—*Wheat: Summary, 1911–1915—Geographic alignments, prices and costs of production.*[1]

| State and geographic division. | Price and cost of production (per bushel). | | | Average yield per acre, 1911–1915. | Gross returns and costs of production per acre. | | | | | Ratio of returns per acre of grain or per bushel to cost (cost = 100 per cent).[3] | Measurement of relationships in percentages of the United States as average base. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average farm price, 1911–1915. | Cost of production, 1909.[2] | | | Average returns per acre of grain, 1911–1915 (price × yield). | Value of products, 1909.[1] | Cost of production, 1909.[1] | | | | Price per bushel. | Cost per bushel, excluding land rental or interest. | Yield per acre. | Value per acre. | Cost of production per acre. | |
| | | Excluding land rental or interest. | Including land rental or interest. | | | | Excluding land rental or interest. | Including land rental or interest. | Commercial fertilizer, in costs per acre. | | | | | | Excluding land rental or interest. | Including land rental or interest. |
| | *Cts.* | *Cts.* | *Cts.* | *Bu.* | *Dolls.* | *Dolls.* | *Dolls.* | *Dolls.* | *Dolls.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| **United States** | 87 | 52 | 74 | 15 | 13.05 | 0.82 | 7.85 | 11.15 | 0.58 | 166 | 100 | 100 | 100 | 100 | 100 | 100 |
| New England | 104 | 71 | 90 | 26 | 27.04 | 5.00 | 18.34 | 23.34 | 5.88 | 147 | 120 | 137 | 173 | 207 | 234 | 209 |
| Middle Atlantic | 99 | 72 | 93 | 19 | 18.81 | 4.51 | 13.76 | 17.58 | 2.98 | 137 | 114 | 138 | 127 | 144 | 175 | 158 |
| South Atlantic | 110 | 80 | 102 | 13 | 14.30 | 1.82 | 10.37 | 13.29 | 2.72 | 138 | 126 | 154 | 87 | 110 | 132 | 119 |
| East North Central | 94 | 52 | 77 | 17 | 15.98 | 1.43 | 8.81 | 13.12 | .85 | 181 | 108 | 100 | 113 | 122 | 112 | 118 |
| West North Central | 85 | 45 | 67 | 15 | 12.75 | .46 | 6.78 | 10.02 | .15 | 188 | 98 | 87 | 100 | 98 | 86 | 90 |
| East South Central | 106 | 65 | 87 | 13 | 13.78 | .71 | 8.39 | 11.35 | 1.44 | 164 | 122 | 125 | 87 | 106 | 107 | 102 |
| West South Central | 93 | 52 | 76 | 13 | 12.09 | .61 | 6.79 | 9.83 | .11 | 178 | 107 | 100 | 87 | 93 | 86 | 88 |
| Mountain | 86 | 39 | 52 | 26 | 22.36 | .79 | 10.05 | 13.61 | .10 | 222 | 99 | 75 | 173 | 171 | 128 | 122 |
| Pacific | 85 | 39 | 57 | 21 | 17.85 | .83 | 8.12 | 11.94 | .16 | 219 | 98 | 75 | 140 | 137 | 103 | 107 |
| New England: | | | | | | | | | | | | | | | | |
| Maine | 107 | 67 | 95 | 25 | 26.75 | | 16.68 | 23.68 | 5.00 | 160 | 123 | 129 | 167 | 205 | 212 | 212 |
| New Hampshire | | | | | | | | | | | | | | | | |
| Vermont | 101 | 74 | 85 | 27 | 27.27 | 5.00 | 20.00 | 23.00 | 6.75 | 136 | 116 | 142 | 180 | 209 | 255 | 206 |
| Massachusetts | | | | | | | | | | | | | | | | |
| Rhode Island | | | | | | | | | | | | | | | | |
| Connecticut | | | | | | | | | | | | | | | | |
| Middle Atlantic: | | | | | | | | | | | | | | | | |
| New York | 99 | 67 | 86 | 21 | 20.79 | 4.25 | 14.09 | 18.00 | 2.50 | 148 | 114 | 129 | 140 | 159 | 179 | 161 |
| New Jersey | 101 | 78 | 100 | 18 | 18.18 | 5.40 | 14.01 | 18.06 | 3.60 | 130 | 116 | 150 | 120 | 139 | 178 | 162 |
| Pennsylvania | 97 | 78 | 98 | 17 | 16.49 | 3.87 | 13.18 | 16.68 | 2.83 | 125 | 111 | 150 | 113 | 126 | 168 | 150 |
| South Atlantic: | | | | | | | | | | | | | | | | |
| Delaware | 98 | 73 | 92 | 17 | 16.66 | 3.30 | 12.41 | 15.56 | 4.15 | 134 | 113 | 140 | 113 | 128 | 158 | 140 |
| Maryland | 97 | 72 | 91 | 16 | 15.52 | 3.10 | 11.57 | 14.60 | 3.06 | 134 | 111 | 138 | 107 | 119 | 147 | 131 |
| Virginia | 102 | 77 | 98 | 13 | 13.26 | 1.43 | 9.95 | 12.69 | 2.54 | 133 | 117 | 148 | 87 | 102 | 127 | 114 |
| West Virginia | 104 | 74 | 96 | 14 | 14.56 | 1.23 | 10.42 | 13.49 | 1.71 | 140 | 120 | 142 | 93 | 112 | 133 | 121 |
| North Carolina | 111 | 83 | 105 | 11 | 12.21 | 1.06 | 9.18 | 11.52 | 2.16 | 133 | 128 | 160 | 73 | 94 | 117 | 103 |
| South Carolina | 131 | 84 | 112 | 11 | 14.41 | 1.07 | 9.28 | 12.31 | 2.66 | 155 | 151 | 162 | 73 | 110 | 118 | 110 |
| Georgia | 124 | 89 | 117 | 11 | 13.64 | 1.53 | 9.79 | 12.85 | 2.73 | 139 | 143 | 171 | 73 | 105 | 125 | 115 |
| Florida | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| East North Central: | | | | | | | | | | | | | | | | |
| Ohio | 98 | 63 | 90 | 16 | 15.68 | 1.64 | 10.15 | 14.37 | 1.76 | 154 | 113 | 121 | 107 | 120 | 129 | 129 |
| Indiana | 95 | 59 | 91 | 15 | 14.25 | 1.18 | 8.80 | 13.59 | 1.20 | 162 | 109 | 113 | 100 | 109 | 112 | 122 |
| Illinois | 93 | 45 | 78 | 16 | 14.88 | .87 | 7.21 | 12.54 | .27 | 206 | 107 | 87 | 107 | 114 | 92 | 112 |
| Michigan | 95 | 59 | 80 | 17 | 16.15 | 1.95 | 10.01 | 13.54 | .95 | 161 | 109 | 113 | 113 | 124 | 128 | 121 |
| Wisconsin | 90 | 41 | 61 | 19 | 17.10 | 1.51 | 7.87 | 11.56 | .08 | 217 | 103 | 79 | 127 | 131 | 100 | 104 |
| West North Central: | | | | | | | | | | | | | | | | |
| Minnesota | 86 | 52 | 71 | 14 | 12.04 | .45 | 7.33 | 10.00 | .18 | 164 | 99 | 100 | 93 | 92 | 93 | 90 |
| Iowa | 85 | 37 | 60 | 19 | 16.15 | 1.01 | 6.94 | 11.47 | .10 | 233 | 98 | 71 | 127 | 124 | 88 | 103 |
| Missouri | 92 | 47 | 69 | 15 | 13.80 | .58 | 7.01 | 10.36 | .46 | 197 | 106 | 90 | 100 | 106 | 89 | 93 |
| North Dakota | 84 | 52 | 69 | 13 | 10.92 | .24 | 6.77 | 8.99 | .06 | 161 | 97 | 100 | 87 | 84 | 86 | 81 |
| South Dakota | 82 | 56 | 82 | 11 | 9.02 | .20 | 6.15 | 8.98 | .11 | 147 | 94 | 108 | 73 | 69 | 78 | 81 |
| Nebraska | 81 | 38 | 59 | 17 | 13.77 | .41 | 6.38 | 10.08 | .09 | 216 | 93 | 73 | 113 | 106 | 81 | 90 |
| Kansas | 86 | 49 | 74 | 14 | 12.04 | .31 | 6.88 | 10.29 | .06 | 175 | 99 | 94 | 93 | 92 | 88 | 92 |
| East South Central: | | | | | | | | | | | | | | | | |
| Kentucky | 99 | 63 | 89 | 13 | 12.87 | .75 | 8.21 | 11.57 | 1.13 | 157 | 114 | 121 | 87 | 99 | 105 | 104 |
| Tennessee | 101 | 66 | 92 | 12 | 12.12 | .86 | 7.90 | 11.03 | 1.15 | 153 | 116 | 127 | 80 | 93 | 101 | 99 |
| Alabama | 120 | 76 | 95 | 12 | 14.40 | .52 | 9.06 | 11.45 | 2.04 | 159 | 138 | 146 | 80 | 110 | 115 | 103 |
| Mississippi | 104 | ...... | ...... | 14 | 14.56 | ...... | ...... | ...... | ...... | ...... | 120 | ...... | 93 | 112 | ...... | ...... |
| West South Central: | | | | | | | | | | | | | | | | |
| Louisiana | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Texas | 99 | 48 | 72 | 14 | 13.86 | .63 | 6.71 | 10.03 | .05 | 207 | 114 | 92 | 93 | 106 | 85 | 90 |
| Oklahoma | 86 | 54 | 78 | 12 | 10.32 | .42 | 6.51 | 9.31 | .03 | 159 | 99 | 104 | 80 | 79 | 83 | 83 |
| Arkansas | 95 | 60 | 84 | 12 | 11.40 | .77 | 7.15 | 10.14 | .24 | 159 | 109 | 115 | 80 | 87 | 91 | 91 |
| Mountain: | | | | | | | | | | | | | | | | |
| Montana | 74 | 37 | 50 | 25 | 18.50 | ...... | 9.22 | 12.47 | ...... | 201 | 85 | 71 | 167 | 142 | 117 | 112 |
| Wyoming | 83 | 37 | 50 | 26 | 21.58 | 1.55 | 9.69 | 12.90 | .22 | 223 | 95 | 71 | 173 | 165 | 123 | 116 |
| Colorado | 80 | 37 | 55 | 22 | 17.60 | .72 | 8.13 | 12.05 | .05 | 216 | 92 | 71 | 147 | 135 | 104 | 108 |
| New Mexico | 93 | 40 | 54 | 22 | 20.46 | 1.10 | 8.72 | 11.85 | ...... | 235 | 107 | 77 | 147 | 157 | 111 | 106 |
| Arizona | 111 | 42 | 48 | 30 | 33.30 | ...... | 12.67 | 14.42 | ...... | 263 | 128 | 81 | 200 | 255 | 161 | 129 |
| Utah | 78 | 48 | 71 | 25 | 19.50 | 1.43 | 12.05 | 17.69 | .36 | 162 | 90 | 92 | 167 | 149 | 154 | 159 |
| Nevada | 93 | ...... | ...... | 29 | 26.97 | ...... | ...... | ...... | ...... | ...... | 107 | ...... | 193 | 207 | ...... | ...... |
| Idaho | 72 | 35 | 50 | 28 | 20.16 | .73 | 9.84 | 13.89 | .07 | 205 | 83 | 67 | 187 | 154 | 125 | 125 |
| Pacific: | | | | | | | | | | | | | | | | |
| Washington | 79 | 36 | 55 | 24 | 18.96 | .95 | 8.67 | 13.10 | .38 | 219 | 91 | 69 | 160 | 145 | 110 | 117 |
| Oregon | 82 | 36 | 54 | 22 | 18.04 | .95 | 7.89 | 11.89 | .08 | 229 | 94 | 69 | 147 | 138 | 101 | 107 |
| California | 95 | 49 | 68 | 16 | 15.20 | .59 | 7.81 | 10.84 | .02 | 195 | 109 | 94 | 107 | 116 | 99 | 97 |

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[1] Costs of production from a special inquiry of the Bureau of Crop Estimates. ("Crop Reporter," May, 1911, p. 36.) Although the data apply to the year 1909, they were collated on a uniform and comparable basis, and for the present purpose of comparing average cost conditions in one State or section with another, they possess particular value.

[2] Cost per bushel obtained by dividing costs per acre, as given in the inquiry cited, by average yield, 1911-1915. It is believed that costs per acre are comparatively stable.

[3] Excluding by-products in returns and land rental in costs. Value of by-products was considered as being offset, roughly, by values of farm manure applied.

Recent figures for cost of production in the United States are not available for any recent period, hence an old inquiry (1909) has been used. For the present purpose of comparing cost conditions in one section of the country with another the figures still possess value. Prices and yields employed are averages for the five years, 1911–1915.

## RETROSPECTIVE VIEW, 1871 TO 1915.

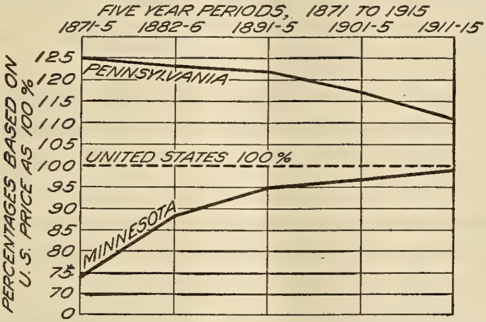
Present tendencies.
Changing sectional price advantage; minimum price moving west and north; decreasing disparity in prices between surplus and deficient wheat regions; shifting conditions in Mountain States.
Trend of yields to the acre, by States and sections.
Trend of value per acre, coordinating price and yield, by States and sections.
Geographic changes in population; wheat production and acreage; per capita production.

Importance appears to attach to the fact that the geographic differences in farm prices are not fixed; that, on the contrary, they are dynamic in character, changing with producing and distributive conditions. Each factor herein is variable. The result may be likened to a slowly moving current in which more or less strong eddies are produced by diverse causes, each circle impinging and merging into the general flow. Mere reference is sufficient here to the continuing agricultural readjustments within the United States, coincident with the westward movement of population, grain, and live-stock production and markets; the transitions from surplus grain production, low land values, and relatively low prices, to a more diversified farming, higher land values, prices, etc.; the increasing wheat deficiency of the older regions, and more recently, development through irrigation of the arid interior. The distance between the eastern areas deficient in wheat production and the surplus-producing territories to the west has steadily widened; this has to some extent been offset by cheapening costs of transportation as well as lower marketing expense. Prices have responded to these transformations, and present geographic tendencies therein may be seen through their indicated development.

The reflection of economic changes can be seen in Table IV (p. 26), showing shifting in geographic price advantages of wheat, from 1871 to 1915. A "wave length" of five years was employed to avoid unusual variations. Particular attention is directed to the percentages, based on the United States figure as 100 per cent.

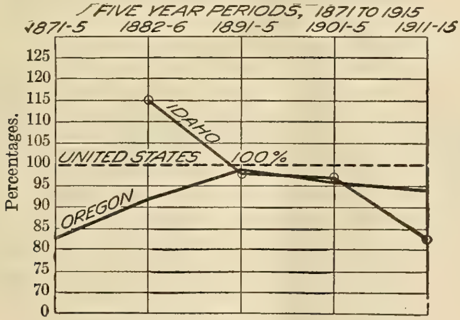
The minimum farm price has moved steadily north and west. In 1871–1875 it appeared in Nebraska; in 1891–1895 in the Dakotas; and in 1911–1915 in Idaho and Montana. During the period covered by Table IV, geographic differences in wheat prices, although still large, have narrowed notably; particularly is this true as between importing eastern and exporting western States. The diminishing price spreads have been attended by decreasing transportation costs and development of distributive methods; also by a decline of wheat growing east of the Mississippi, as well as by comparative concentration of the national wheat production within the West North Central group. A steady increase may be seen in the relative prices of the great wheat States of this group compared with the United States as a whole; on the other hand, a rapid decrease took place in the Mountain States. Farmers in wheat-importing States of the

FIG. 5.—Decreasing farm-price differences between Pennsylvania (importing State) and Minnesota (exporting State).



| | | 1871–75 | 1882–86 | 1891–95 | 1901–5 | 1911–15 |
|---|---|---|---|---|---|---|
| Pennsylvania | Per cent | 125 | 123 | 122 | 117 | 111 |
| | Price | $1.27 | $0.96 | $0.73 | $0.84 | $0.97 |
| Minnesota | Per cent | 74 | 88 | 95 | 97 | 99 |
| | Price | $0.75 | $0.69 | $0.57 | $0.70 | $0.86 |

FIG. 6.—Changing farm-price ratios, Idaho (transition from importing to exporting State) and Oregon (exporting State).



| | | 1871–75 | 1882–86 | 1891–95 | 1901–5 | 1911–15 |
|---|---|---|---|---|---|---|
| Idaho | Per cent | | 115 | 98 | 97 | 83 |
| | Price | | $0.90 | $0.59 | $0.70 | $0.72 |
| Oregon | Per cent | 83 | 92 | 98 | 96 | 94 |
| | Price | $0.85 | $0.72 | $0.59 | $0.69 | $0.82 |

Mountain division still receive relatively high prices for their wheat, but in wheat-exporting regions of this division the lowest farm prices prevail.

As an illustration, in figure 5 the course of price differences between Pennsylvania, an importing State, and Minnesota, an exporting wheat State, has been plotted. The difference in the price per bushel at the first period (1871–1875) was 52 cents; at the last (1911–1915), 11 cents.

Similarly, in figure 6 the course of prices in Idaho, showing a transition from a State producing insufficient wheat at the beginning of the period to its present status as an exporting State, has been compared with that of Oregon, an exporting State. When a deficiency State the disadvantage of its position resulted in a wheat price in Idaho 115 per cent of the United States average; and as an exporting State, disadvantageously situated as to wheat markets, its ratio has declined to 83 per cent of the average; but Oregon, a consistently exporting State, has increased its price ratio from 83 to 94 per cent.

Details are shown in Table IV.

TABLE IV.—*Farm prices of wheat, 1871 to 1915.*

[A review, by States and sections, of the trend of geographic price differences.]

| State and geographic division. | Farm prices per bushel, in 5-year averages. | | | | | Measurement of changes in percentages of the United States average as base (100 per cent). | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886[1] | 1871–1875[2] | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886[1] | 1871–1875 |
| | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| **United States** | **87** | **72** | **60** | **78** | **102** | **100** | **100** | **100** | **100** | **100** |
| New England | 104 | 100 | 90 | 122 | 151 | 120 | 138 | 150 | 156 | 148 |
| Middle Atlantic | 99 | 86 | 76 | 97 | 131 | 114 | 119 | 127 | 124 | 128 |
| East North Central | 94 | 79 | 62 | 81 | 102 | 108 | 110 | 103 | 104 | 100 |
| West North Central | 85 | 67 | 53 | 66 | 81 | 98 | 93 | 88 | 85 | 79 |
| South Atlantic | 110 | 93 | 79 | 100 | 136 | 126 | 129 | 132 | 128 | 133 |
| East South Central | 106 | 90 | 76 | 98 | 124 | 122 | 125 | 126 | 125 | 122 |
| West South Central | 93 | 79 | 69 | 94 | 132 | 107 | 110 | 115 | 121 | 129 |
| Mountain | 86 | 81 | 68 | 91 | ...... | 99 | 112 | 113 | 117 | ...... |
| Pacific | 85 | 71 | 59 | 75 | 102 | 98 | 99 | 98 | 96 | 100 |
| New England: | | | | | | | | | | |
| Maine | 107 | 99 | 93 | 130 | 158 | 123 | 137 | 155 | 167 | 155 |
| New Hampshire | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Vermont | 101 | 100 | 86 | 115 | 144 | 116 | 139 | 143 | 146 | 141 |
| Massachusetts | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Rhode Island | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Connecticut | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Middle Atlantic: | | | | | | | | | | |
| New York | 99 | 87 | 78 | 97 | 131 | 114 | 121 | 130 | 124 | 128 |
| New Jersey | 101 | 86 | 78 | 99 | 136 | 116 | 119 | 130 | 127 | 133 |
| Pennsylvania | 97 | 84 | 73 | 96 | 127 | 111 | 117 | 122 | 123 | 125 |
| East North Central: | | | | | | | | | | |
| Ohio | 98 | 83 | 65 | 87 | 110 | 113 | 115 | 108 | 112 | 108 |
| Indiana | 95 | 81 | 61 | 82 | 102 | 109 | 112 | 102 | 105 | 100 |
| Illinois | 93 | 77 | 59 | 78 | 95 | 107 | 107 | 98 | 100 | 93 |
| Michigan | 95 | 81 | 65 | 83 | 114 | 109 | 112 | 108 | 106 | 112 |
| Wisconsin | 90 | 75 | 60 | 76 | 87 | 103 | 104 | 100 | 97 | 85 |

[1] 1882–1886 taken instead of 1881–1885 in view of availability of statistics for a larger number of States beginning 1882.

[2] Values reduced to gold basis.

TABLE IV.—*Farm prices of wheat, 1871 to 1915*—Continued.

| State and geographic division. | Farm prices per bushel in 5 year averages. | | | | | Measurement of changes in percentages of the United States average as base (100 per cent). | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886[1] | 1871–1875[2] | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886[1] | 1871 1875 |
| West North Central: | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* | *P.ct.* |
| Minnesota | 86 | 70 | 57 | 69 | 75 | 99 | 97 | 95 | 88 | 74 |
| Iowa | 85 | 68 | 57 | 66 | 71 | 98 | 94 | 95 | 85 | 70 |
| Missouri | 92 | 75 | 56 | 75 | 98 | 106 | 104 | 93 | 96 | 96 |
| North Dakota | 84 | 65 | 49 | 63 | ...... | 97 | 90 | 82 | 81 | ...... |
| South Dakota | 82 | 62 | 50 | | | 94 | 86 | 83 | | |
| Nebraska | 81 | 62 | 50 | 57 | 66 | 93 | 86 | 83 | 73 | 65 |
| Kansas | 86 | 67 | 51 | 63 | 94 | 99 | 93 | 85 | 81 | 92 |
| South Atlantic: | | | | | | | | | | |
| Delaware | 98 | 83 | 71 | 96 | 135 | 113 | 115 | 118 | 123 | 132 |
| Maryland | 97 | 82 | 74 | 94 | 130 | 111 | 114 | 123 | 121 | 127 |
| Virginia | 102 | 87 | 72 | 93 | 122 | 117 | 121 | 120 | 119 | 120 |
| West Virginia | 104 | 88 | 74 | 93 | 117 | 120 | 122 | 123 | 119 | 115 |
| North Carolina | 111 | 98 | 80 | 103 | 128 | 128 | 136 | 133 | 132 | 125 |
| South Carolina | 131 | 108 | 95 | 114 | 174 | 151 | 150 | 158 | 146 | 171 |
| Georgia | 124 | 104 | 90 | 109 | 146 | 143 | 144 | 150 | 140 | 143 |
| East South Central: | | | | | | | | | | |
| Kentucky | 99 | 85 | 65 | 85 | 105 | 114 | 118 | 108 | 109 | 103 |
| Tennessee | 101 | 87 | 66 | 86 | 109 | 116 | 121 | 110 | 110 | 107 |
| Alabama | 120 | 98 | 90 | 108 | 133 | 138 | 136 | 150 | 138 | 130 |
| Mississippi | 104 | 92 | 82 | 111 | 147 | 120 | 128 | 137 | 142 | 144 |
| West South Central: | | | | | | | | | | |
| Arkansas | 95 | 83 | 70 | 96 | 128 | 109 | 115 | 117 | 123 | 125 |
| Louisiana | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oklahoma | 86 | 69 | ...... | ...... | ...... | 99 | 96 | ...... | ...... | ...... |
| Texas | 99 | 86 | 68 | 91 | 137 | 114 | 119 | 113 | 117 | 134 |
| Mountain: | | | | | | | | | | |
| Montana | 74 | 71 | 68 | 92 | ...... | 85 | 98 | 113 | 118 | ...... |
| Idaho | 72 | 70 | 59 | 90 | ...... | 83 | 97 | 98 | 115 | ...... |
| Wyoming | 83 | 77 | 68 | 88 | ...... | 95 | 107 | 113 | 113 | ...... |
| Colorado | 80 | 74 | 61 | 80 | ...... | 92 | 103 | 102 | 103 | ...... |
| New Mexico | 93 | 86 | 80 | 103 | ...... | 107 | 119 | 133 | 132 | ...... |
| Arizona | 111 | 103 | 77 | 102 | ...... | 128 | 143 | 128 | 131 | ...... |
| Utah | 78 | 76 | 59 | 78 | ...... | 90 | 106 | 98 | 100 | ...... |
| Nevada | 93 | 91 | 72 | 99 | 164 | 107 | 126 | 120 | 127 | 161 |
| Pacific: | | | | | | | | | | |
| Washington | 79 | 65 | 52 | 73 | ...... | 91 | 90 | 87 | 94 | ...... |
| Oregon | 82 | 69 | 59 | 72 | 85 | 94 | 96 | 98 | 92 | 83 |
| California | 95 | 79 | 67 | 80 | 120 | 109 | 110 | 112 | 103 | 118 |

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[1] 1882–1886 taken instead of 1881–1885 in view of availability of statistics for a larger number of States beginning 1882.

[2] Values reduced to gold basis.

Data associating shifting geographic differences in farm prices per bushel of wheat with trend of yields to the acre are given in Table V (p. 28), and value per acre in Table VI (p. 29). These tables are self-explanatory. Absolute figures as well as percentages are given, but the changes can be followed more easily through the percentages based upon the United States figure as 100 per cent.

### TABLE V.—*Wheat: Trend of yields per acre, 1871–1915.*

[Limitations of soil and climate, reflected in yields per acre, as qualifying price factors.]

| State and geographic division. | Yield per acre, in 5-year averages. | | | | | Comparison of changes in percentages of the United States average as base. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1911–1915. | 1901–1905. | 1891–1895. | 1882–1886. | 1871–1875. | 1911–1915. | 1901–1905. | 1891–1895. | 1882–1886. | 1871–1875. |
| | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *Bu.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| **United States** | 15 | 14 | 13 | 12 | 12 | 100 | 100 | 100 | 100 | 100 |
| New England | 26 | 22 | 20 | 16 | 16 | 173 | 157 | 154 | 133 | 133 |
| Middle Atlantic | 19 | 16 | 15 | 14 | 14 | 127 | 114 | 115 | 117 | 117 |
| East North Central | 17 | 15 | 15 | 13 | 12 | 113 | 107 | 115 | 108 | 100 |
| West North Central | 15 | 14 | 13 | 13 | 13 | 100 | 100 | 100 | 108 | 108 |
| South Atlantic | 13 | 10 | 10 | 8 | 9 | 87 | 71 | 77 | 67 | 75 |
| East South Central | 13 | 9 | 9 | 6 | 9 | 87 | 64 | 69 | 50 | 75 |
| West South Central | 13 | 10 | 10 | 8 | 13 | 87 | 71 | 77 | 67 | 108 |
| Mountain | 26 | 23 | 19 | 17 | ...... | 173 | 164 | 146 | 142 | ...... |
| Pacific | 21 | 18 | 16 | 15 | 16 | 140 | 129 | 123 | 125 | 133 |
| New England: | | | | | | | | | | |
| Maine | 25 | 24 | 18 | 14 | 14 | 167 | 171 | 138 | 117 | 117 |
| New Hampshire | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Vermont | 27 | 20 | 21 | 18 | 17 | 180 | 143 | 161 | 150 | 142 |
| Massachusetts | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Rhode Island | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Connecticut | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Middle Atlantic: | | | | | | | | | | |
| New York | 21 | 16 | 16 | 15 | 13 | 140 | 114 | 123 | 125 | 108 |
| New Jersey | 18 | 15 | 14 | 13 | 15 | 120 | 107 | 108 | 108 | 125 |
| Pennsylvania | 17 | 16 | 15 | 13 | 14 | 113 | 114 | 115 | 108 | 117 |
| East North Central: | | | | | | | | | | |
| Ohio | 16 | 15 | 16 | 13 | 12 | 107 | 107 | 123 | 108 | 100 |
| Indiana | 15 | 14 | 15 | 13 | 11 | 100 | 100 | 115 | 108 | 92 |
| Illinois | 16 | 15 | 15 | 12 | 12 | 107 | 107 | 115 | 100 | 100 |
| Michigan | 17 | 15 | 15 | 16 | 13 | 113 | 107 | 115 | 133 | 108 |
| Wisconsin | 19 | 16 | 14 | 13 | 14 | 127 | 114 | 108 | 108 | 117 |
| West North Central: | | | | | | | | | | |
| Minnesota | 14 | 13 | 15 | 13 | 15 | 93 | 93 | 115 | 108 | 125 |
| Iowa | 19 | 13 | 15 | 11 | 12 | 127 | 93 | 115 | 92 | 100 |
| Missouri | 15 | 14 | 13 | 11 | 12 | 100 | 100 | 100 | 92 | 100 |
| North Dakota | 13 | 14 | 14 | 14 | ...... | 87 | 100 | 108 | 117 | ...... |
| South Dakota | 11 | 12 | 11 | | | 73 | 86 | 85 | | |
| Nebraska | 17 | 17 | 11 | 13 | 12 | 113 | 121 | 85 | 108 | 100 |
| Kansas | 14 | 14 | 12 | 15 | 14 | 93 | 100 | 92 | 125 | 117 |
| South Atlantic: | | | | | | | | | | |
| Delaware | 17 | 15 | 13 | 11 | 11 | 113 | 107 | 100 | 92 | 92 |
| Maryland | 16 | 15 | 15 | 12 | 11 | 107 | 107 | 115 | 100 | 92 |
| Virginia | 13 | 9 | 10 | 8 | 8 | 87 | 64 | 77 | 67 | 67 |
| West Virginia | 14 | 10 | 11 | 10 | 10 | 93 | 71 | 85 | 83 | 83 |
| North Carolina | 11 | 7 | 7 | 6 | 7 | 73 | 50 | 54 | 50 | 58 |
| South Carolina | 11 | 7 | 6 | 6 | 6 | 73 | 50 | 46 | 50 | 50 |
| Georgia | 11 | 7 | 7 | 6 | 7 | 73 | 50 | 54 | 50 | 58 |
| Florida | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| East South Central: | | | | | | | | | | |
| Kentucky | 13 | 10 | 12 | 9 | 10 | 87 | 71 | 92 | 75 | 83 |
| Tennessee | 12 | 9 | 9 | 6 | 8 | 80 | 64 | 69 | 50 | 67 |
| Alabama | 12 | 9 | 8 | 6 | 8 | 80 | 64 | 62 | 50 | 67 |
| Mississippi | 14 | 9 | 8 | 5 | 10 | 93 | 64 | 62 | 42 | 83 |
| West South Central: | | | | | | | | | | |
| Arkansas | 12 | 9 | 9 | 7 | 10 | 80 | 64 | 69 | 58 | 83 |
| Louisiana | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oklahoma | 12 | 12 | 11 | ...... | ...... | 80 | 86 | 85 | ...... | ...... |
| Texas | 14 | 10 | 11 | 10 | 16 | 93 | 71 | 85 | 86 | 133 |
| Mountain: | | | | | | | | | | |
| Montana | 25 | 26 | 22 | 18 | ...... | 167 | 186 | 169 | 150 | ...... |
| Idaho | 28 | 23 | 20 | 17 | ...... | 187 | 164 | 154 | 142 | ...... |
| Wyoming | 26 | 23 | 20 | 17 | ...... | 173 | 164 | 154 | 142 | ...... |
| Colorado | 22 | 23 | 19 | 19 | ...... | 147 | 164 | 146 | 158 | ...... |
| New Mexico | 22 | 18 | 16 | 14 | ...... | 147 | 129 | 123 | 108 | ...... |
| Arizona | 30 | 23 | 17 | 14 | ...... | 200 | 164 | 131 | 117 | ...... |
| Utah | 25 | 23 | 19 | 17 | ...... | 167 | 164 | 146 | 142 | ...... |
| Nevada | 29 | 27 | 19 | 18 | 21 | 193 | 193 | 146 | 150 | 175 |
| Pacific: | | | | | | | | | | |
| Washington | 24 | 24 | 17 | 16 | ...... | 160 | 171 | 131 | 133 | ...... |
| Oregon | 22 | 19 | 18 | 16 | 19 | 147 | 136 | 138 | 133 | 158 |
| California | 16 | 11 | 13 | 12 | 12 | 107 | 79 | 100 | 100 | 100 |

### TABLE VI.—*Wheat: Gross returns per acre.*

[Coordinating price per bushel and yield per acre. A review of the trend of returns per acre of wheat, 1871–1915, and measurement of tendencies in absolute and relative figures.]

| State and geographic division. | Gross returns per acre, in 5-year averages. | | | | | Comparisons in percentages of the United States average as base (100). | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886 | 1871–1875 | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886 | 1871–1875 |
| | *Dolls.* | *Dolls.* | *Dolls.* | *Dolls.* | *Dolls.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* | *P. ct.* |
| **United States** | **13.05** | **10.08** | **7.80** | **9.36** | **12.24** | **100** | **100** | **100** | **100** | **100** |
| New England | 27.01 | 21.88 | 17.40 | 19.45 | 23.30 | 207 | 217 | 224 | 208 | 190 |
| Middle Atlantic | 18.49 | 13.42 | 11.45 | 13.30 | 18.40 | 142 | 133 | 147 | 142 | 150 |
| East North Central | 15.61 | 11.90 | 9.31 | 10.90 | 12.56 | 120 | 118 | 119 | 116 | 103 |
| West North Central | 12.53 | 9.27 | 6.91 | 8.36 | 10.52 | 96 | 92 | 89 | 89 | 86 |
| South Atlantic | 14.32 | 9.01 | 7.61 | 8.31 | 11.46 | 110 | 89 | 98 | 89 | 94 |
| East South Central | 13.49 | 8.36 | 6.88 | 6.21 | 11.14 | 103 | 83 | 88 | 66 | 91 |
| West South Central | 11.86 | 8.12 | 6.89 | 7.91 | 17.36 | 91 | 81 | 88 | 85 | 142 |
| Mountain | 22.26 | 18.81 | 12.84 | 15.10 | ...... | 171 | 187 | 165 | 161 | ...... |
| Pacific | 17.40 | 12.47 | 9.39 | 10.93 | 15.28 | 133 | 124 | 120 | 117 | 125 |
| New England: | | | | | | | | | | |
| Maine | 26.75 | 23.76 | 16.74 | 18.20 | 22.12 | 205 | 236 | 215 | 194 | 181 |
| New Hamsphire | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Vermont | 27.27 | 20.00 | 18.06 | 20.70 | 24.48 | 209 | 198 | 232 | 221 | 200 |
| Massachusetts | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Rhode Island | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Connecticut | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Middle Atlantic: | | | | | | | | | | |
| New York | 20.79 | 13.92 | 12.48 | 14.55 | 17.03 | 159 | 138 | 160 | 155 | 139 |
| New Jersey | 18.18 | 12.90 | 10.92 | 12.87 | 20.40 | 139 | 128 | 140 | 137 | 167 |
| Pennsylvania | 16.49 | 13.44 | 10.95 | 12.48 | 17.78 | 126 | 133 | 140 | 133 | 145 |
| East North Central: | | | | | | | | | | |
| Ohio | 15.68 | 12.45 | 10.40 | 11.31 | 13.20 | 120 | 124 | 133 | 121 | 108 |
| Indiana | 14.25 | 11.34 | 9.15 | 10.66 | 11.22 | 109 | 112 | 117 | 114 | 92 |
| Illinois | 14.88 | 11.55 | 8.85 | 9.36 | 11.40 | 114 | 115 | 113 | 100 | 93 |
| Michigan | 16.15 | 12.15 | 9.75 | 13.28 | 14.82 | 124 | 121 | 125 | 142 | 121 |
| Wisconsin | 17.10 | 12.00 | 8.40 | 9.88 | 12.18 | 131 | 119 | 108 | 106 | 100 |
| West North Central: | | | | | | | | | | |
| Minnesota | 12.04 | 9.10 | 8.55 | 8.97 | 11.25 | 92 | 90 | 110 | 96 | 92 |
| Iowa | 16.15 | 8.84 | 8.55 | 7.26 | 8.52 | 124 | 88 | 110 | 78 | 70 |
| Missouri | 13.80 | 10.50 | 7.28 | 8.25 | 11.76 | 106 | 104 | 93 | 88 | 96 |
| North Dakota | 10.92 | 9.10 | 6.86 | 8.82 | ...... | 84 | 90 | 88 | 94 | ...... |
| South Dakota | 9.02 | 7.44 | 5.50 | | | 69 | 74 | 71 | | |
| Nebraska | 13.77 | 10.54 | 5.50 | 7.41 | 7.92 | 106 | 105 | 71 | 79 | 65 |
| Kansas | 12.04 | 9.38 | 6.12 | 9.45 | 13.16 | 92 | 93 | 78 | 101 | 108 |
| South Atlantic: | | | | | | | | | | |
| Delaware | 16.66 | 12.45 | 9.23 | 10.56 | 14.85 | 128 | 124 | 118 | 113 | 121 |
| Maryland | 15.52 | 12.30 | 11.10 | 11.28 | 14.30 | 119 | 122 | 142 | 121 | 117 |
| Virginia | 13.26 | 7.83 | 7.20 | 7.44 | 9.76 | 102 | 78 | 92 | 79 | 80 |
| West Virginia | 14.56 | 8.80 | 8.14 | 9.30 | 11.70 | 112 | 87 | 104 | 99 | 95 |
| North Carolina | 12.21 | 6.86 | 5.60 | 6.18 | 8.96 | 94 | 68 | 72 | 66 | 73 |
| South Carolina | 14.41 | 7.56 | 5.70 | 6.84 | 10.44 | 110 | 75 | 73 | 73 | 85 |
| Georgia | 13.64 | 7.28 | 6.30 | 6.54 | 10.22 | 105 | 72 | 81 | 70 | 83 |
| Florida | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| East South Central: | | | | | | | | | | |
| Kentucky | 12.87 | 8.50 | 7.80 | 7.65 | 10.50 | 99 | 84 | 100 | 82 | 86 |
| Tennessee | 12.12 | 7.83 | 5.94 | 5.16 | 8.72 | 93 | 78 | 76 | 55 | 71 |
| Alabama | 14.40 | 8.82 | 7.20 | 6.48 | 10.64 | 110 | 87 | 92 | 69 | 87 |
| Mississippi | 14.56 | 8.28 | 6.56 | 5.55 | 14.70 | 112 | 81 | 84 | 59 | 120 |
| West South Central: | | | | | | | | | | |
| Arkansas | 11.40 | 7.47 | 6.30 | 6.72 | 12.80 | 87 | 74 | 81 | 71 | 105 |
| Louisiana | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... |
| Oklahoma | 10.32 | 8.28 | ...... | ...... | ...... | 79 | 81 | ...... | ...... | ...... |
| Texas | 13.86 | 8.60 | 7.48 | 9.10 | 21.92 | 106 | 85 | 96 | 97 | 179 |
| Mountain: | | | | | | | | | | |
| Montana | 18.50 | 18.46 | 14.96 | 16.56 | ...... | 142 | 183 | 192 | 177 | ...... |
| Idaho | 20.16 | 16.10 | 11.80 | 15.30 | ...... | 154 | 160 | 151 | 163 | ...... |
| Wyoming | 21.58 | 17.71 | 13.60 | 14.96 | ...... | 165 | 176 | 174 | 160 | ...... |
| Colorado | 17.60 | 17.02 | 11.59 | 15.20 | ...... | 135 | 169 | 149 | 162 | ...... |
| New Mexico | 20.46 | 15.48 | 12.80 | 13.39 | ...... | 157 | 154 | 164 | 143 | ...... |
| Arizona | 33.30 | 23.69 | 13.09 | 14.28 | ...... | 255 | 235 | 168 | 153 | ...... |
| Utah | 19.50 | 17.48 | 11.21 | 13.26 | ...... | 149 | 173 | 144 | 142 | ...... |
| Nevada | 26.97 | 24.57 | 13.68 | 17.82 | 34.44 | 207 | 244 | 175 | 190 | 281 |
| Pacific: | | | | | | | | | | |
| Washington | 18.96 | 15.60 | 8.84 | 11.68 | ...... | 145 | 155 | 113 | 125 | ...... |
| Oregon | 18.04 | 13.11 | 10.62 | 11.52 | 16.15 | 138 | 130 | 136 | 123 | 132 |
| California | 15.20 | 8.69 | 8.71 | 9.60 | 14.40 | 116 | 86 | 112 | 103 | 118 |

TABLE VII.—*Wheat: Review, 1871 to 1915.*

[Geographic distribution of wheat production and acreage in absolute and relative figures, adjustments of production to population.]

| State and geographic division. | Production, in five-year averages, showing geographic distribution. [000 omitted.] | | | | | Average 1911–1915 as compared with 1901–1905 (100 per cent). | Trend of production per capita; i. e., ratio of wheat supplies to increasing population. (bushels per inhabitant).[1] | | | | | Distribution of wheat production in percentages of United States totals. | | | | | Per cent of all improved land occupied by wheat.[2] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886 | 1871–1875 | | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886 | 1871–1875 | 1911–1915 | 1901–1905 | 1891–1895 | 1882–1886 | 1871–1875 | 1909 | 1899 | 1889 | 1879 |
| **United States** | **803,501** | **660,345** | **491,721** | **450,480** | **272,443** | **122** | **8.3** | **8.2** | **7.4** | **8.2** | **6.5** | **100.0** | **100.0** | **100.0** | **100.0** | **100.0** | **9.3** | **12.7** | **9.4** | **12.4** |
| New England | 107 | 226 | 462 | 1,187 | 937 | 47 | (3) | (3) | .1 | .3 | .3 | (4) | (4) | 0.1 | 0.3 | 0.3 | 0.1 | 0.1 | 0.1 | 0.6 |
| Middle Atlantic | 30,798 | 35,760 | 29,232 | 31,430 | 25,130 | 86 | 1.5 | 2.2 | 2.2 | 2.8 | 2.7 | 3.8 | 5.4 | 5.9 | 7.0 | 9.2 | 5.5 | 7.2 | 6.0 | 7.0 |
| South Atlantic | 37,187 | 32,877 | 27,874 | 26,566 | 20,570 | 113 | 2.9 | 3.0 | 3.0 | 3.3 | 3.2 | 4.6 | 5.0 | 5.7 | 5.9 | 7.6 | 4.6 | 7.3 | 6.4 | 9.0 |
| East North Central | 124,045 | 106,542 | 136,914 | 145,855 | 104,777 | 116 | 6.5 | 6.4 | 9.6 | 12.0 | 10.7 | 15.4 | 16.1 | 27.8 | 32.3 | 38.5 | 7.9 | 12.0 | 11.8 | 16.1 |
| West North Central | 416,425 | 345,102 | 202,973 | 156,639 | 71,183 | 121 | 34.5 | 32.1 | 21.7 | 21.6 | 15.7 | 51.8 | 52.3 | 41.3 | 34.8 | 26.1 | 15.7 | 18.5 | 12.6 | 19.2 |
| East South Central | 19,196 | 18,111 | 19,908 | 20,749 | 17,909 | 106 | 2.2 | 2.3 | 2.9 | 3.5 | 3.8 | 2.4 | 2.7 | 4.0 | 4.6 | 6.6 | 3.0 | 7.4 | 5.1 | 8.6 |
| West South Central | 41,381 | 33,447 | 9,100 | 6,763 | 2,524 | 124 | 4.3 | 4.6 | 1.7 | 1.7 | 1.0 | 5.2 | 5.1 | 1.9 | 1.5 | 0.9 | 2.7 | 7.4 | 1.6 | 3.1 |
| Mountain | 59,765 | 22,593 | 8,355 | 7,324 | 336 | 265 | 20.3 | 11.5 | 6.2 | 8.4 | 0.8 | 7.5 | 3.4 | 1.7 | 1.6 | 0.1 | 8.1 | 11.2 | 6.0 | 10.9 |
| Pacific | 74,597 | 65,687 | 56,903 | 53,967 | 26,648 | 114 | 15.6 | 22.3 | 27.8 | 37.9 | 33.0 | 9.3 | 10.0 | 11.6 | 12.0 | 9.8 | 15.2 | 24.8 | 21.5 | 17.7 |
| The Territories | ...... | ...... | ...... | ...... | 2,429 | ...... | ...... | ...... | ...... | ...... | 6.0 | ...... | ...... | ...... | ...... | .9 | ...... | ...... | ...... | ...... |
| New England: | | | | | | | | | | | | | | | | | | | | |
| Maine | 80 | 192 | 199 | 584 | 271 | 42 | .1 | .3 | .3 | .9 | .4 | (4) | (4) | (4) | .1 | .1 | .1 | .3 | .1 | 1.3 |
| New Hampshire | ...... | ...... | 63 | 169 | 182 | ...... | (3) | (3) | .2 | .5 | .6 | (4) | (4) | (4) | (4) | .1 | (4) | (4) | .1 | .5 |
| Vermont | 27 | 34 | 197 | 379 | 411 | 79 | .1 | .1 | .6 | 1.1 | 1.2 | (4) | (4) | (4) | .1 | .1 | (4) | .1 | .3 | .6 |
| Massachusetts | ...... | ...... | ...... | 19 | 34 | ...... | (3) | (3) | (3) | (3) | (3) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | (4) |
| Rhode Island | ...... | ...... | ...... | ...... | ...... | ...... | (3) | (3) | (3) | (3) | (3) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | (4) |
| Connecticut | ...... | ...... | 3 | 36 | 39 | ...... | (3) | (3) | (3) | (3) | .1 | (3) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | .1 |
| Middle Atlantic: | | | | | | | | | | | | | | | | | | | | |
| New York | 7,348 | 8,242 | 7,897 | 10,913 | 7,542 | 89 | .8 | 1.1 | 1.2 | 2.0 | 1.6 | .9 | 1.2 | 1.6 | 2.4 | 2.8 | 1.9 | 3.6 | 2.8 | 4.2 |
| New Jersey | 1,463 | 1,709 | 1,765 | 1,968 | 1,923 | 86 | .5 | .8 | 1.1 | 1.6 | 2.0 | .2 | .3 | .3 | .5 | .7 | 4.6 | 6.7 | 6.1 | 7.1 |
| Pennsylvania | 21,987 | 25,809 | 19,570 | 18,549 | 15,665 | 85 | 2.7 | 3.8 | 3.5 | 4.0 | 4.2 | 2.7 | 3.9 | 4.0 | 4.1 | 5.7 | 9.7 | 11.5 | 10.0 | 10.8 |
| South Atlantic: | | | | | | | | | | | | | | | | | | | | |
| Delaware | 1,936 | 1,681 | 1,269 | 1,062 | 632 | 115 | 9.3 | 8.8 | 7.3 | 6.8 | 4.8 | .2 | .3 | .3 | .2 | .2 | 15.6 | 15.7 | 12.4 | 11.7 |
| Maryland | 9,981 | 11,618 | 7,387 | 7,444 | 5,036 | 86 | 7.5 | 9.5 | 6.8 | 7.6 | 6.1 | 1.2 | 1.8 | 1.5 | 1.7 | 1.9 | 17.6 | 18.0 | 15.0 | 17.0 |
| Virginia | 11,295 | 7,198 | 7,485 | 6,507 | 6,192 | 157 | 5.3 | 3.8 | 4.4 | 4.1 | 4.7 | 1.4 | 1.1 | 1.5 | 1.4 | 2.3 | 7.0 | 9.2 | 8.1 | 10.6 |
| West Virginia | 3,442 | 3,788 | 4,285 | 3,397 | 2,649 | 91 | 2.6 | 3.6 | 5.2 | 5.0 | 5.4 | .4 | .6 | .9 | .8 | 1.0 | 3.8 | 8.1 | 7.7 | 10.4 |
| North Carolina | 7,345 | 4,387 | 4,845 | 4,075 | 2,908 | 167 | 3.2 | 2.2 | 2.8 | 2.7 | 2.5 | .9 | .6 | 1.0 | .9 | 1.1 | 5.7 | 9.0 | 8.5 | 10.0 |
| South Carolina | 1,199 | 1,949 | 905 | 1,276 | 620 | 62 | .8 | 1.4 | .7 | 1.2 | .8 | .2 | .3 | .2 | .3 | .2 | .7 | 3.0 | 2.2 | 4.1 |
| Georgia | 1,989 | 2,256 | 1,698 | 2,805 | 2,533 | 88 | .7 | 1.0 | .9 | 1.7 | 2.0 | .3 | .3 | .3 | .6 | .9 | .8 | 3.0 | 2.1 | 5.8 |
| Florida | ...... | ...... | ...... | ...... | ...... | ...... | (3) | (3) | (3) | (3) | (3) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | (4) |
| East North Central: | | | | | | | | | | | | | | | | | | | | |
| Ohio | 31,566 | 29,586 | 40,626 | 34,296 | 19,768 | 107 | 6.4 | 6.8 | 10.6 | 10.1 | 7.0 | 3.9 | 4.5 | 8.3 | 7.6 | 7.3 | 9.5 | 16.7 | 12.4 | 14.1 |
| Indiana | 34,950 | 27,858 | 38,442 | 34,914 | 20,003 | 125 | 12.7 | 10.8 | 16.8 | 16.9 | 11.3 | 4.3 | 4.2 | 7.8 | 7.8 | 7.3 | 12.3 | 17.3 | 17.0 | 18.8 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Illinois | 38,631 | 26,144 | 26,255 | 29,014 | 27,153 | 148 | 6.5 | 5.2 | 6.4 | 8.6 | 10.0 | 4.8 | 4.0 | 5.3 | 6.4 | 10.0 | 7.8 | 6.6 | 8.7 | 12.3 |
| Michigan | 15,198 | 14,759 | 21,890 | 28,986 | 15,713 | 103 | 5.2 | 5.8 | 10.0 | 15.9 | 11.9 | 1.9 | 2.2 | 4.4 | 6.4 | 5.8 | 6.3 | 16.3 | 15.2 | 22.0 |
| Wisconsin | 3,700 | 8,195 | 9,701 | 18,645 | 22,140 | 45 | 1.5 | 3.8 | 5.4 | 12.7 | 19.5 | .5 | 1.2 | 2.0 | 4.1 | 8.1 | 1.2 | 4.9 | 7.6 | 21.3 |
| West North Central: | | | | | | | | | | | | | | | | | | | | |
| Minnesota | 59,081 | 74,257 | 46,115 | 37,050 | 22,362 | 80 | 27.1 | 40.2 | 32.3 | 37.3 | 41.3 | 7.4 | 11.3 | 9.4 | 8.2 | 8.2 | 16.7 | 35.6 | 30.3 | 42.0 |
| Iowa | 14,098 | 14,680 | 13,197 | 29,413 | 27,758 | 96 | 6.3 | 6.6 | 6.6 | 16.9 | 21.0 | 1.8 | 2.2 | 2.7 | 6.5 | 10.2 | 1.8 | 5.7 | 2.3 | 15.3 |
| Missouri | 35,377 | 32,957 | 21,541 | 22,424 | 11,798 | 107 | 10.5 | 10.4 | 7.7 | 9.4 | 6.4 | 4.4 | 5.0 | 4.4 | 5.0 | 4.3 | 8.2 | 9.0 | 9.8 | 12.4 |
| North Dakota | 105,887 | 61,388 | 41,647 | 21,707 | | 172 | 160.2 | 155.0 | 181.9 | 73.3 | | 13.1 | 9.3 | 8.5 | 4.8 | (5) | 40.0 | 46.2 | 58.2 | 23.1 |
| South Dakota | 39,258 | 43,716 | 25,440 | | .......... | 90 | 61.1 | 95.9 | 69.9 | | ...... | 4.9 | 6.6 | 5.2 | | | 20.3 | 35.3 | 32.5 | |
| Nebraska | 59,844 | 43,269 | 13,596 | 22,277 | 2,998 | 138 | 48.5 | 39.2 | 12.8 | 32.0 | 13.5 | 7.4 | 6.6 | 2.7 | 5.0 | 1.1 | 10.9 | 13.8 | 5.2 | 26.7 |
| Kansas | 102,880 | 74,835 | 41,437 | 23,768 | 6,267 | 137 | 58.4 | 48.7 | 28.8 | 20.3 | 11.3 | 12.8 | 11.3 | 8.4 | 5.3 | 2.3 | 20.0 | 15.2 | 7.1 | 17.3 |
| East South Central: | | | | | | | | | | | | | | | | | | | | |
| Kentucky | 9,813 | 8,602 | 11,182 | 11,290 | 7,210 | 114 | 4.2 | 3.9 | 5.7 | 6.5 | 5.1 | 1.2 | 1.3 | 2.3 | 2.5 | 2.6 | 4.7 | 10.4 | 7.6 | 10.8 |
| Tennessee | 8,789 | 8,497 | 7,855 | 7,709 | 9,423 | 103 | 3.9 | 4.1 | 4.3 | 4.7 | 7.0 | 1.1 | 1.3 | 1.6 | 1.7 | 3.5 | 5.7 | 13.9 | 9.4 | 14.1 |
| Alabama | 528 | 982 | 748 | 1,530 | 1,020 | 54 | .2 | .5 | .5 | 1.1 | .9 | .1 | .1 | .1 | .3 | .4 | .1 | 1.4 | .5 | 4.2 |
| Mississippi | 66 | 30 | 123 | 220 | 256 | 220 | (3) | (3) | .1 | .2 | .3 | (4) | (4) | (4) | .1 | .1 | (4) | .1 | (4) | .8 |
| West South Central: | | | | | | | | | | | | | | | | | | | | |
| Louisiana | .......... | .......... | .......... | 7 | .......... | .......... | (3) | (3) | (3) | (3) | (3) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | (4) | .1 |
| Texas | 13,637 | 11,635 | 5,084 | 5,107 | 1,463 | 117 | 3.3 | 3.5 | 2.0 | 2.8 | 1.4 | 1.7 | 1.8 | 1.1 | 1.1 | .5 | 1.2 | 5.3 | 1.7 | 3.0 |
| Oklahoma | 26,217 | [6]19,600 | 2,454 | .......... | (5) | 134 | 13.5 | [6]18.6 | 5.9 | ...... | (5) | 3.3 | [6]3.0 | .5 | ...... | (5) | 6.7 | [6]17.8 | .4 | ..... |
| Arkansas | 1,527 | 2,212 | 1,562 | 1,649 | 1,061 | 69 | .9 | 1.6 | 1.3 | 1.8 | 1.8 | .2 | .3 | .3 | .4 | .4 | .7 | 5.5 | 2.6 | 5.7 |
| Mountain: | | | | | | | | | | | | | | | | | | | | |
| Montana | 20,900 | 2,587 | 1,173 | 1,245 | (5) | 808 | 49.9 | 9.1 | 6.8 | 15.4 | (5) | 2.6 | .4 | .2 | .3 | (5) | 7.1 | 5.3 | 2.0 | 6.7 |
| Wyoming | 2,366 | 560 | 121 | 43 | (5) | 422 | 14.5 | 5.1 | 1.7 | 1.2 | (5) | 1.9 | .1 | (4) | (4) | (5) | 3.3 | 2.5 | 1.0 | .3 |
| Colorado | 10,709 | 6,504 | 2,262 | 2,231 | (5) | 165 | 12.1 | 10.5 | 5.0 | 7.9 | (5) | .3 | 1.0 | .5 | .5 | (5) | 7.9 | 13.0 | 7.0 | 10.5 |
| New Mexico | 1,542 | 789 | 751 | 924 | (5) | 195 | 4.2 | 3.4 | 4.4 | 6.8 | (5) | 1.4 | .1 | .2 | .2 | (5) | 2.2 | 11.6 | 8.3 | 21.6 |
| Arizona | 879 | 418 | 239 | 263 | (5) | 210 | 3.8 | 2.8 | 2.4 | 4.5 | (5) | .2 | .1 | .1 | .1 | (5) | 5.7 | 9.6 | 6.0 | 16.1 |
| Utah | 6,601 | 4,221 | 2,086 | 1,594 | (5) | 156 | 16.3 | 13.8 | 9.0 | 9.3 | (5) | .1 | .6 | .4 | .3 | (5) | 13.0 | 18.3 | 15.4 | 17.4 |
| Nevada | 1,246 | 601 | 161 | 95 | 336 | 207 | 13.1 | 11.1 | 3.5 | 1.7 | 6.9 | .8 | .1 | (4) | (4) | 0.1 | 1.9 | 3.2 | 0.5 | 1.1 |
| Idaho | 15,522 | 6,913 | 1,562 | 929 | (5) | 225 | 41.0 | 32.8 | 14.2 | 16.9 | (5) | .2 | 1.0 | .3 | .2 | (5) | 14.4 | 18.8 | 10.5 | 11.2 |
| Pacific: | | | | | | | | | | | | | | | | | | | | |
| Washington | 49,985 | 28,567 | 9,482 | 4,943 | (5) | 175 | 37.2 | 40.5 | 23.4 | 26.3 | (5) | 6.2 | 4.3 | 1.9 | 1.1 | (6) | 33.2 | 31.4 | 20.5 | 16.8 |
| Oregon | 18,018 | 14,508 | 11,205 | 13,135 | 3,440 | 124 | 23.8 | 29.5 | 32.2 | 56.6 | 29.7 | 2.2 | 2.2 | 2.3 | 2.9 | 1.3 | 17.9 | 26.2 | 15.7 | 20.2 |
| California | 6,594 | 22,612 | 36,216 | 35,889 | 23,208 | 29 | 2.5 | 12.9 | 28.0 | 35.7 | 35.6 | .9 | 3.5 | 7.4 | 8.0 | 8.5 | 4.2 | 22.4 | 23.2 | 17.2 |
| The Territories | .......... | .......... | .......... | .......... | 2,429 | .......... | ...... | ...... | ...... | ...... | 6.0 | ...... | ...... | ...... | ...... | .9 | ..... | ..... | ..... | ..... |
| United States—Total | 803,501 | 660,345 | 491,721 | 450,480 | 272,443 | 122 | 8.3 | 8.2 | 7.4 | 8.2 | 6.5 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 9.3 | 12.7 | 9.4 | 12.4 |
| Domestic exports, wheat and wheat flour: | | | | | | | | | | | | | | | | | | | | |
| Quantity | 188,748 | 140,026 | 170,624 | 128,057 | 66,037 | .......... | ...... | (8) | (8) | (8) | (8) | ...... | ...... | ...... | ...... | ...... | ..... | ..... | ..... | ..... |
| Per cent of production | 23.5 | 21.2 | 34.7 | 28.4 | 24.2 | [7]135 | [8]1.9 | 1.7 | 2.6 | 2.3 | 1.6 | ...... | ...... | ...... | ...... | ...... | ..... | ..... | ..... | ..... |

---

[1] Five-year averages, production divided by population. Average population calculated by prorating differences between decennial census periods.

[2] From decennial census returns.

[3] Less than one-tenth of 1 bushel.

[4] Less than one-tenth of 1 per cent.

[5] Included in "The Territories."

[6] Includes Indian Territory.

[7] Ratio 1911-1915 compared to 1901-1905.

[8] Exports per capita.

## TREND OF WHEAT PRODUCTION IN RELATION TO POPULATION, BY STATES AND SECTIONS.

Although production nearly trebled since 1871 in proportion to population, it has remained stationary since 1882–1886.

A generally diminishing proportion of improved acreage in wheat, increased production being due to new brought areas under cultivation.

Increasing wheat deficiency east of the Mississippi.

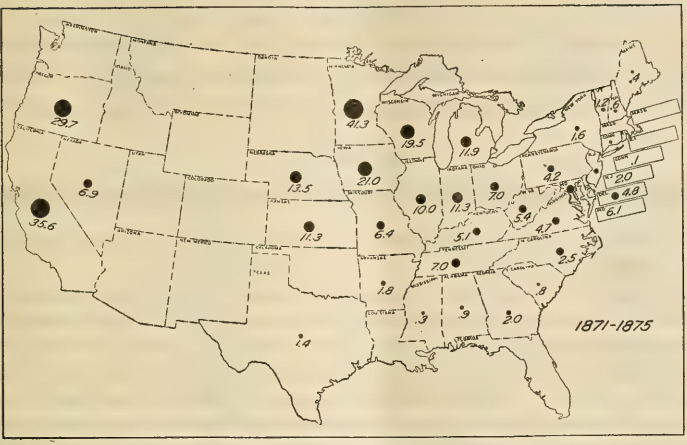
Only in the Mountain States is wheat production increasing more rapidly than population.

Finally, in Table VII (p. 30), are assembled some of the fundamental factors in this retrospective review of prices and price conditions from 1871 to 1915. Units of measurement are geographic divisions (to permit of a general view) and States. The rate of increase of population in relation to wheat production is given in the per capita figures; the shifting in sources of wheat is indicated by State and sectional percentages of the United States production from decade to decade, as well as by the fractions of the total improved land occupied by wheat.

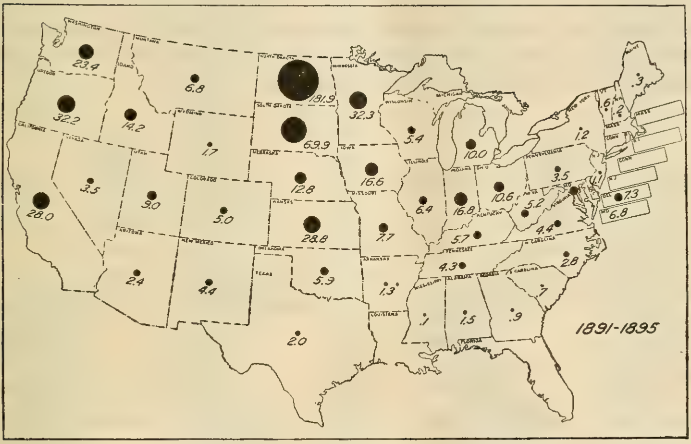
Although during the period covered by this table the wheat production in the United States almost trebled, in proportion to population it has remained stationary since 1882–1886 (8.2 bushels per capita as against 8.3 bushels in 1911–1915). Moreover, a notable and general decline is registered in the proportion of wheat in the total improved land, even in the wheat belt, showing that the increase in production was due to new areas being brought under cultivation, as well as to some slight progress in the yields to the acre. This would be shown more markedly in the last period but for the unusually large wheat crops of 1914 and 1915, due to the stimulating effect of disturbed international conditions.

The proportion of wheat produced east of the Mississippi dropped from 62.2 per cent of the United States total to 26.2 per cent. The East North Central division shows a decline from 38.5 per cent of the national total to 15.4 per cent (Wisconsin dropping from 19.5 to 1.5 bushels per capita); the West North Central division has a corresponding gain. But even in this last division, now producing over half the total wheat, the rate of increase has suffered a notable decline, and population increase is rapidly outstripping wheat production.

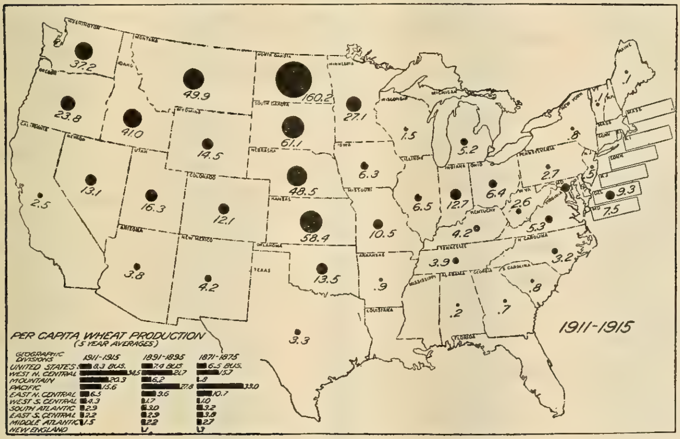
It is only in the Mountain States that any considerable recent growth in the ratio of wheat production to population is shown, but here also it appears to be traceable to new areas brought under cultivation. As yet this region, though gaining at a rapid rate (increase of 265 per cent of 1911–1915 over 1901–1905 as 100 per cent), contributes but 7.5 per cent of the total wheat. According to the 1910 census, 2 per cent of its area was then improved, but within recent years irrigation has added much territory to the producing regions.



MAP 5.—Per capita wheat production, by States, 1871–75.



MAP 6.—Per capita wheat production, by States, 1891–95.



MAP 7.—Per capita wheat production, by States, 1911–15.

[Circles and figures within each State represent wheat production per capita, at 20-year intervals: 1871–75, 1891–95, and 1911–15.]

The three maps on the preceding page (maps 5, 6, and 7) show, through different dimensions of the circles, the per capita wheat production, by States, in 1871–1875, 1891–1895, and 1911–1915; i. e., progress of wheat production in relation to increasing population.

## APPENDIX.

### AVERAGE FARM PRICES OF WHEAT, BY COUNTIES, 1910–1914.

NOTE.—The data which follow form the bases of maps 1, 3, and 4, and are explained on pages 11 and 24.

Counties have been used as the smallest effective unit of measurement, for the reason that the usual State prices are frequently averages for large expanses of territory with dissimilar physical and price conditions. The basic figures were compiled from returns of some 30,000 township reporters for each of the five years 1910–1914, inclusive, as of December 1. Observations for this period and for a like date of each year were employed to distinguish normal geographic variations from temporary deviations; and to further conduce thereto the price averages have been rounded to a 5-cent unit to overcome occasional minor differences due to such causes as local variations in grade.

As the figures are designed to show geographic variation in prices paid to wheat producers, counties with little or no wheat production have been omitted (those with less than 500 acres in wheat, according to the 1910 census).

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Alabama | 100–104 | Dekalb. |
| | | Jackson. |
| | | Lauderdale. |
| | | Limestone. |
| | | Madison. |
| Arizona | 95–99 | Graham. |
| | | Maricopa. |
| | | Pinal. |
| Arkansas | 90–94 | Benton. |
| | | Boone. |
| | | Carroll. |
| | | Madison. |
| | | Marion. |
| | | Washington. |
| | 95–99 | Baxter. |
| | | Clay. |
| | | Fulton. |
| | | Greene. |
| | | Independence. |
| | | Izard. |
| | | Newton. |
| | | Randolph. |
| | | Searcy. |
| | | Sharp. |
| | | Stone. |
| California | 80–84 | Lassen. |
| | | Modoc. |
| | 85–89 | Shasta. |
| | | Siskiyou. |
| | 90–94 | Butte. |
| | | Colusa. |
| | | Glenn. |
| | | Lake. |
| | | Sutter. |
| | | Yolo. |
| | 95–99 | Fresno. |
| | | Kern. |
| | | Kings. |
| | | Madera. |
| | | Merced. |
| | | Monterey. |
| California (continued). | 95–99 | Napa. |
| | | Sacramento. |
| | | San Benito. |
| | | San Joaquin. |
| | | San Luis Obispo. |
| | | Solano. |
| | | Stanislaus. |
| | | Tulare. |
| | 100–104 | Alameda. |
| | | Contra Costa. |
| | | Los Angeles. |
| | | Orange. |
| | | Riverside. |
| | | San Diego. |
| | | Santa Barbara. |
| | | Ventura. |
| Colorado | 75–79 | Larimer. |
| | | Logan. |
| | | Morgan. |
| | | Phillips. |
| | | Sedgwick. |
| | | Washington. |
| | | Weld. |
| | | Yuma. |
| | 80–84 | Adams. |
| | | Arapahoe. |
| | | Boulder. |
| | | Cheyenne. |
| | | Denver. |
| | | Douglas. |
| | | Elbert. |
| | | El Paso. |
| | | Jefferson. |
| | | Kit Carson. |
| | | Lincoln. |
| | 85–89 | Bent. |
| | | Conejos. |
| | | Costilla. |
| | | Crowley. |
| | | Eagle. |
| | | Garfield. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
|  | *Cents.* |  |
| Colorado (continued). | 85–89 | Kiowa. |
|  |  | Moffat. |
|  |  | Otero. |
|  |  | Prowers. |
|  |  | Rio Blanco. |
|  |  | Rio Grande. |
|  |  | Routt. |
|  |  | Saguache. |
|  | 90–94 | Delta. |
|  |  | Dolores. |
|  |  | La Plata. |
|  |  | Mesa. |
|  |  | Montezuma. |
|  |  | Montrose. |
|  |  | Ouray. |
|  |  | San Miguel. |
| Connecticut. (None) |  |  |
| Delaware | 95–99 | Kent. |
|  |  | New Castle. |
|  |  | Sussex. |
| Florida. (None.) |  |  |
| Georgia | 105–109 | Catoosa. |
|  |  | Dade. |
|  |  | Fannin. |
|  |  | Gilmer. |
|  |  | Gordon. |
|  |  | Murray. |
|  |  | Pickens. |
|  |  | Towns. |
|  |  | Union. |
|  |  | Walker. |
|  |  | Whitfield. |
|  | 110–114 | Bartow. |
|  |  | Chattooga. |
|  |  | Cherokee. |
|  |  | Dawson. |
|  |  | Floyd. |
|  |  | Forsyth. |
|  |  | Hall. |
|  |  | Lumpkin. |
|  |  | White. |
|  | 115 or over | Clarke. |
|  |  | Cobb. |
|  |  | Elbert. |
|  |  | Fayette. |
|  |  | Franklin. |
|  |  | Gwinnett. |
|  |  | Haralson. |
|  |  | Hart. |
|  |  | Henry. |
|  |  | Jackson. |
|  |  | Madison. |
|  |  | Milton. |
|  |  | Monroe. |
|  |  | Newton. |
|  |  | Oconee. |
|  |  | Oglethorpe. |
|  |  | Paulding. |
|  |  | Pike. |
|  |  | Polk. |
|  |  | Spalding. |
|  |  | Walton. |
| Idaho | 65–69 | Bannock. |
|  |  | Bear Lake. |
|  |  | Bingham. |
|  |  | Bonneville. |
|  |  | Fremont. |
|  | 70–74 | Blaine. |
|  |  | Cassia. |
|  |  | Custer. |
|  |  | Franklin. |
|  |  | Gooding. |
|  |  | Lincoln. |
|  |  | Minidoka. |
|  |  | Oneida. |
|  |  | Power. |
|  |  | Twin Falls. |
|  | *Cents.* |  |
| Idaho (continued) | 75–79 | Adams. |
|  |  | Clearwater. |
|  |  | Idaho. |
|  |  | Kootenai. |
|  |  | Latah. |
|  |  | Lemhi. |
|  |  | Lewis. |
|  |  | Nez Perce. |
|  |  | Washington. |
|  | 80–84 | Ada. |
|  |  | Boise. |
|  |  | Canyon. |
|  |  | Elmore. |
| Illinois | 85–89 | Carroll. |
|  |  | Champaign. |
|  |  | Coles. |
|  |  | Dewitt. |
|  |  | Douglas. |
|  |  | Henderson. |
|  |  | Henry. |
|  |  | Jo Daviess. |
|  |  | Lee. |
|  |  | McDonough. |
|  |  | McLean. |
|  |  | Macon. |
|  |  | Mercer. |
|  |  | Moultrie. |
|  |  | Ogle. |
|  |  | Piatt. |
|  |  | Rock Island. |
|  |  | Warren. |
|  |  | Whiteside. |
|  | 90–94 | Adams. |
|  |  | Brown. |
|  |  | Bureau. |
|  |  | Calhoun. |
|  |  | Cass. |
|  |  | Christian. |
|  |  | Clark. |
|  |  | Crawford. |
|  |  | Cumberland. |
|  |  | Edgar. |
|  |  | Edwards. |
|  |  | Ford. |
|  |  | Fulton. |
|  |  | Greene. |
|  |  | Grundy. |
|  |  | Hancock. |
|  |  | Iroquois. |
|  |  | Jasper. |
|  |  | Jersey. |
|  |  | Kane. |
|  |  | Kankakee. |
|  |  | Kendall. |
|  |  | Knox. |
|  |  | La Salle. |
|  |  | Lawrence. |
|  |  | Livingston. |
|  |  | Logan. |
|  |  | McHenry. |
|  |  | Macoupin. |
|  |  | Marshall. |
|  |  | Mason. |
|  |  | Menard. |
|  |  | Montgomery. |
|  |  | Morgan. |
|  |  | Peoria. |
|  |  | Pike. |
|  |  | Putnam. |
|  |  | Sangamon. |
|  |  | Schuyler. |
|  |  | Scott. |
|  |  | Shelby. |
|  |  | Stark. |
|  |  | Tazewell. |
|  |  | Vermilion. |
|  |  | Wabash. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Illinois (continued). | 90–94 | Wayne. |
| | | White. |
| | | Will. |
| | | Woodford. |
| | 95–99 | Alexander. |
| | | Bond. |
| | | Clay. |
| | | Clinton. |
| | | Cook. |
| | | Dupage. |
| | | Effingham. |
| | | Fayette. |
| | | Franklin. |
| | | Gallatin. |
| | | Hamilton. |
| | | Hardin. |
| | | Jackson. |
| | | Jefferson. |
| | | Johnson. |
| | | Lake. |
| | | Madison. |
| | | Marion. |
| | | Massac. |
| | | Monroe. |
| | | Perry. |
| | | Pope. |
| | | Pulaski. |
| | | Randolph. |
| | | Richland. |
| | | St. Clair. |
| | | Saline. |
| | | Union. |
| | | Washington. |
| | | Williamson. |
| Indiana | 90–94 | Benton. |
| | | Boone. |
| | | Carroll. |
| | | Cass. |
| | | Clay. |
| | | Clinton. |
| | | Crawford. |
| | | Daviess. |
| | | Dubois. |
| | | Fountain. |
| | | Fulton. |
| | | Gibson. |
| | | Grant. |
| | | Greene. |
| | | Hamilton. |
| | | Hancock. |
| | | Harrison. |
| | | Hendricks. |
| | | Henry. |
| | | Howard. |
| | | Jasper. |
| | | Johnson. |
| | | Knox. |
| | | Kosciusko. |
| | | Lake. |
| | | Laporte. |
| | | Lawrence. |
| | | Madison. |
| | | Marion. |
| | | Marshall. |
| | | Martin. |
| | | Miami. |
| | | Montgomery. |
| | | Morgan. |
| | | Newton. |
| | | Orange. |
| | | Owen. |
| | | Parke. |
| | | Perry. |
| | | Pike. |
| | | Porter. |
| | | Posey. |
| | | Pulaski. |
| | | Putnam. |
| | | Rush. |
| Indiana (continued) | 90–94 | Shelby. |
| | | Spencer. |
| | | Starke. |
| | | Sullivan. |
| | | Tippecanoe. |
| | | Tipton. |
| | | Vanderburg. |
| | | Vermilion. |
| | | Vigo. |
| | | Warren. |
| | | Warrick. |
| | | White. |
| | 95–99 | Adams. |
| | | Allen. |
| | | Bartholomew. |
| | | Blackford. |
| | | Brown. |
| | | Clark. |
| | | Dearborn. |
| | | Decatur. |
| | | Dekalb. |
| | | Delaware. |
| | | Elkhart. |
| | | Fayette. |
| | | Floyd. |
| | | Franklin. |
| | | Huntington. |
| | | Jackson. |
| | | Jay. |
| | | Jefferson. |
| | | Jennings. |
| | | Lagrange. |
| | | Monroe. |
| | | Noble. |
| | | Ohio. |
| | | Randolph. |
| | | Ripley. |
| | | St. Joseph. |
| | | Scott. |
| | | Steuben. |
| | | Switzerland. |
| | | Union. |
| | | Wabash. |
| | | Washington. |
| | | Wayne. |
| | | Wells. |
| | | Whitley. |
| Iowa | 85–89 | Adair. |
| | | Adams. |
| | | Allamakee. |
| | | Appanoose. |
| | | Audubon. |
| | | Boone. |
| | | Carroll. |
| | | Cass. |
| | | Cedar. |
| | | Cherokee. |
| | | Clarke. |
| | | Clayton. |
| | | Clinton. |
| | | Crawford. |
| | | Dallas. |
| | | Davis. |
| | | Decatur. |
| | | Des Moines. |
| | | Dubuque. |
| | | Fayette. |
| | | Fremont. |
| | | Guthrie. |
| | | Hamilton. |
| | | Hancock. |
| | | Hardin. |
| | | Harrison. |
| | | Henry. |
| | | Humboldt. |
| | | Ida. |
| | | Iowa. |
| | | Jackson. |
| | | Jasper. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Iowa (continued) | 85–89 | Jefferson. |
| | | Johnson. |
| | | Keokuk. |
| | | Kossuth. |
| | | Lee. |
| | | Louisa. |
| | | Lucas. |
| | | Lyon. |
| | | Madison. |
| | | Mahaska. |
| | | Marion. |
| | | Marshall. |
| | | Mills. |
| | | Monona. |
| | | Monroe. |
| | | Montgomery. |
| | | Muscatine. |
| | | Page. |
| | | Plymouth. |
| | | Polk. |
| | | Pottawattamie. |
| | | Poweshiek. |
| | | Ringgold. |
| | | Scott. |
| | | Shelby. |
| | | Sioux. |
| | | Story. |
| | | Tama. |
| | | Taylor. |
| | | Union. |
| | | Van Buren. |
| | | Wapello. |
| | | Warren. |
| | | Washington. |
| | | Wayne. |
| | | Webster. |
| | | Winnebago. |
| | | Winneshiek. |
| | | Woodbury. |
| | | Worth. |
| | | Wright. |
| Kansas | 80–84 | Cheyenne. |
| | | Decatur. |
| | | Graham. |
| | | Norton. |
| | | Osborne. |
| | | Phillips. |
| | | Rawlins. |
| | | Rooks. |
| | | Sheridan. |
| | | Sherman. |
| | | Smith. |
| | | Thomas. |
| | 85–89 | Allen. |
| | | Anderson. |
| | | Barber. |
| | | Barton. |
| | | Bourbon. |
| | | Brown. |
| | | Butler. |
| | | Chase. |
| | | Chautauqua. |
| | | Cherokee. |
| | | Clark. |
| | | Clay. |
| | | Cloud. |
| | | Coffey. |
| | | Comanche. |
| | | Cowley. |
| | | Crawford. |
| | | Dickinson. |
| | | Doniphan. |
| | | Edwards. |
| | | Elk. |
| | | Ellis. |
| | | Ellsworth. |
| | | Finney. |
| | | Ford. |
| | | Franklin. |
| Kansas (continued) | 85–89 | Geary. |
| | | Gove. |
| | | Grant. |
| | | Gray. |
| | | Greeley. |
| | | Greenwood. |
| | | Hamilton. |
| | | Harper. |
| | | Harvey. |
| | | Haskell. |
| | | Hodgeman. |
| | | Jackson. |
| | | Jewell. |
| | | Kearny. |
| | | Kingman. |
| | | Kiowa. |
| | | Labette. |
| | | Lane. |
| | | Lincoln. |
| | | Linn. |
| | | Logan. |
| | | Lyon. |
| | | McPherson. |
| | | Marion. |
| | | Marshall. |
| | | Meade. |
| | | Mitchell. |
| | | Montgomery. |
| | | Morris. |
| | | Morton. |
| | | Nemaha. |
| | | Neosho. |
| | | Ness. |
| | | Osage. |
| | | Ottawa. |
| | | Pawnee. |
| | | Pottawatomie. |
| | | Pratt. |
| | | Reno. |
| | | Republic. |
| | | Rice. |
| | | Riley. |
| | | Rush. |
| | | Russell. |
| | | Saline. |
| | | Scott. |
| | | Sedgwick. |
| | | Seward. |
| | | Shawnee. |
| | | Stafford. |
| | | Stanton. |
| | | Stevens. |
| | | Sumner. |
| | | Trego. |
| | | Wabaunsee. |
| | | Wallace. |
| | | Washington. |
| | | Wichita. |
| | | Wilson. |
| | | Woodson. |
| | 90–94 | Atchison. |
| | | Douglas. |
| | | Jefferson. |
| | | Johnson. |
| | | Leavenworth. |
| | | Miami. |
| | | Wyandotte. |
| Kentucky | 90–94 | Adair. |
| | | Allen. |
| | | Anderson. |
| | | Ballard. |
| | | Barren. |
| | | Bath. |
| | | Boone. |
| | | Bourbon. |
| | | Boyd. |
| | | Boyle. |
| | | Bracken. |
| | | Breckenridge. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Kentucky (continued). | 90–94 | Bullitt. |
| | 95–99 | Butler. |
| | | Caldwell. |
| | | Calloway. |
| | | Campbell. |
| | | Carlisle. |
| | | Carroll. |
| | | Carter. |
| | | Casey. |
| | | Christian. |
| | | Clark. |
| | | Clinton. |
| | | Crittenden. |
| | | Cumberland. |
| | | Daviess. |
| | | Edmonson. |
| | | Elliott. |
| | | Fayette. |
| | | Fleming. |
| | | Franklin. |
| | | Fulton. |
| | | Gallatin. |
| | | Garrard. |
| | | Grant. |
| | | Graves. |
| | | Grayson. |
| | | Green. |
| | | Greenup. |
| | | Hancock. |
| | | Hardin. |
| | | Harrison. |
| | | Hart. |
| | | Henderson. |
| | | Henry. |
| | | Hickman. |
| | | Hopkins. |
| | | Jefferson. |
| | | Jessamine. |
| | | Kenton. |
| | | Larue. |
| | | Laurel. |
| | | Lawrence. |
| | | Lewis. |
| | | Lincoln. |
| | | Livingston. |
| | | Logan. |
| | | Lyon. |
| | | McCracken. |
| | | McCreary. |
| | | McLean. |
| | | Madison. |
| | | Marion. |
| | | Marshall. |
| | | Mason. |
| | | Meade. |
| | | Mercer. |
| | | Metcalfe. |
| | | Monroe. |
| | | Montgomery. |
| | | Muhlenberg. |
| | | Nelson. |
| | | Ohio. |
| | | Oldham. |
| | | Owen. |
| | | Pendleton. |
| | | Pulaski. |
| | | Robertson. |
| | | Rockcastle. |
| | | Russell. |
| | | Scott |
| | | Shelby. |
| | | Simpson. |
| | | Spencer. |
| | | Taylor. |
| | | Todd. |
| | | Trigg. |
| | | Trimble. |
| | | Union. |
| | | Warren. |
| | *Cents.* | |
| Kentucky (continued). | 95–99 | Washington. |
| | | Wayne. |
| | | Webster. |
| | | Woodford. |
| Louisiana. (None.) | | |
| Maine. (None.) | | |
| Maryland | 95–99 | Allegany. |
| | | Anne Arundel. |
| | | Baltimore. |
| | | Calvert. |
| | | Caroline. |
| | | Carroll. |
| | | Cecil. |
| | | Charles. |
| | | Dorchester. |
| | | Frederick. |
| | 95–99 | Harford. |
| | | Howard. |
| | | Kent. |
| | | Montgomery. |
| | | Prince Georges. |
| | | Queen Annes. |
| | | St. Marys. |
| | | Talbot. |
| | | Washington. |
| | 100–104 | Garrett. |
| | | Somerset. |
| | | Wicomico. |
| | | Worcester. |
| Mass. (None.) | | |
| Michigan | 90–94 | Alcona. |
| | | Alpena. |
| | | Antrim. |
| | | Arenac. |
| | | Bay. |
| | | Benzie. |
| | | Charlevoix. |
| | | Clare. |
| | | Emmet. |
| | | Gladwin. |
| | | Grand Traverse. |
| | | Gratiot. |
| | | Iosco. |
| | | Isabella. |
| | | Kalkaska. |
| | | Lake. |
| | | Leelanau. |
| | | Manistee. |
| | | Mason. |
| | | Mecosta. |
| | | Midland. |
| | | Missaukee. |
| | | Montcalm. |
| | | Newaygo. |
| | | Oceana. |
| | | Ogemaw. |
| | | Osceola. |
| | | Presque Isle |
| | | Wexford. |
| | 95–99 | Allegan. |
| | | Barry. |
| | | Berrien. |
| | | Branch. |
| | | Calhoun. |
| | | Cass. |
| | | Clinton. |
| | | Eaton. |
| | | Genesee. |
| | | Hillsdale. |
| | | Huron. |
| | | Ingham. |
| | | Ionia. |
| | | Jackson. |
| | | Kalamazoo. |
| | | Kent. |
| | | Lapeer. |
| | | Lenawee. |
| | | Livingston. |
| | | Macomb. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Michigan (continued). | 95–99 | Monroe. |
| | | Muskegon. |
| | | Oakland. |
| | | Ottawa. |
| | | Saginaw. |
| | | St. Clair. |
| | | St. Joseph. |
| | | Sanilac. |
| | | Shiawassee. |
| | | Tuscola. |
| | | Van Buren. |
| | | Washtenaw. |
| | | Wayne. |
| Minnesota | 85–89 | Becker. |
| | | Beltrami. |
| | | Bigstone. |
| | | Chippewa. |
| | | Clay. |
| | | Clearwater. |
| | | Cottonwood. |
| | | Dodge. |
| | | Douglas. |
| | | Faribault. |
| | | Fillmore. |
| | | Freeborn. |
| | | Grant. |
| | | Houston. |
| | | Hubbard. |
| | | Jackson. |
| | | Kandiyohi. |
| | | Kittson. |
| | | Lac qui Parle. |
| | | Lincoln. |
| | | Lyon. |
| | | Mahnomen. |
| | | Marshall. |
| | | Martin. |
| | | Mower. |
| | | Murray. |
| | | Nobles. |
| | | Norman. |
| | | Olmsted. |
| | | Otter Tail. |
| | | Pennington. |
| | | Pipestone. |
| | | Polk. |
| | | Pope. |
| | | Red Lake. |
| | | Redwood. |
| | | Renville. |
| | | Rock. |
| | | Roseau. |
| | | Stevens. |
| | | Swift. |
| | | Todd. |
| | | Traverse. |
| | | Wabasha. |
| | | Wadena. |
| | | Wilkin. |
| | | Winona. |
| | | Yellow Medicine. |
| | 90–94 | Anoka. |
| | | Benton. |
| | | Blue Earth. |
| | | Brown. |
| | | Carver. |
| | | Chisago. |
| | | Crow Wing. |
| | | Dakota. |
| | | Goodhue. |
| | | Hennepin. |
| | | Isanti. |
| | | Kanabec. |
| | | Le Sueur. |
| | | McLeod. |
| | | Meeker. |
| | | Mille Lacs. |
| | | Morrison. |
| | | Nicollet. |
| | *Cents.* | |
| Minnesota (continued). | 90–94 | Pine. |
| | | Ramsey. |
| | | Rice. |
| | | Scott. |
| | | Sherburne. |
| | | Sibley. |
| | | Stearns. |
| | | Steele. |
| | | Waseca. |
| | | Washington. |
| | | Watonwan. |
| | | Wright. |
| Mississippi. (None.) | | |
| Missouri | 85–89 | Andrew. |
| | | Atchison. |
| | | Caldwell. |
| | | Carroll. |
| | | Chariton. |
| | | Cooper. |
| | | Daviess. |
| | | Dekalb. |
| | | Gentry. |
| | | Grundy. |
| | | Harrison. |
| | | Holt. |
| | | Howard. |
| | | Linn. |
| | | Livingston. |
| | | Mercer. |
| | | Nodaway. |
| | | Pettis. |
| | | Putnam. |
| | | Saline. |
| | | Sullivan. |
| | | Worth. |
| | 90–94 | Adair. |
| | | Audrain. |
| | | Barry. |
| | | Barton. |
| | | Bates. |
| | | Benton. |
| | | Bollinger. |
| | | Boone. |
| | | Buchanan. |
| | | Callaway. |
| | | Camden. |
| | | Cape Girardeau. |
| | | Carter. |
| | | Cass. |
| | | Cedar. |
| | | Christian. |
| | | Clark. |
| | | Clay. |
| | | Clinton. |
| | | Cole. |
| | | Crawford. |
| | | Dade. |
| | | Dallas. |
| | | Dent. |
| | | Douglas. |
| | | Franklin. |
| | | Gasconade. |
| | | Greene. |
| | | Henry. |
| | | Hickory. |
| | | Howell. |
| | | Jackson. |
| | | Jasper. |
| | | Jefferson. |
| | | Johnson. |
| | | Knox. |
| | | Laclede. |
| | | Lafayette. |
| | | Lawrence. |
| | | Lewis. |
| | | Lincoln. |
| | | McDonald. |
| | | Macon. |
| | | Madison. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Missouri (continued). | 90–94 | Maries. |
| | | Marion. |
| | | Miller. |
| | | Moniteau. |
| | | Monroe. |
| | | Montgomery. |
| | | Morgan. |
| | | Newton. |
| | | Oregon. |
| | | Osage. |
| | | Ozark. |
| | | Perry. |
| | | Phelps. |
| | | Pike. |
| | | Platte. |
| | | Polk. |
| | | Pulaski. |
| | | Ralls. |
| | | Randolph. |
| | | Ray. |
| | | Ripley. |
| | | St. Charles. |
| | | St. Clair. |
| | | Ste. Genevieve. |
| | | St. Francois. |
| | | St. Louis. |
| | | Schuyler. |
| | | Scotland. |
| | | Shannon. |
| | | Shelby. |
| | | Stone. |
| | | Taney. |
| | | Texas. |
| | | Vernon. |
| | | Warren. |
| | | Washington. |
| | | Webster. |
| | | Wright. |
| | 95–99 | Butler. |
| | | Dunklin. |
| | | Iron. |
| | | Mississippi. |
| | | New Madrid. |
| | | Pemiscot. |
| | | Reynolds. |
| | | Scott. |
| | | Stoddard. |
| | | Wayne. |
| Montana | 70–74 | Blaine. |
| | | Carbon. |
| | | Cascade. |
| | | Chouteau. |
| | | Fergus. |
| | | Flathead. |
| | | Gallatin. |
| | | Hill. |
| | | Lincoln. |
| | | Madison. |
| | | Meagher. |
| | | Park. |
| | | Sanders. |
| | | Stillwater. |
| | | Sweet Grass. |
| | | Teton. |
| | | Yellowstone. |
| | 75–79 | Beaverhead. |
| | | Big Horn. |
| | | Broadwater. |
| | | Custer. |
| | | Dawson. |
| | | Deerlodge. |
| | | Granite. |
| | | Jefferson. |
| | | Lewis and Clark. |
| | | Missoula. |
| | | Musselshell. |
| | | Powell. |
| | | Ravalli. |
| | | Rosebud. |
| | *Cents.* | |
| Montana (continued). | 75–79 | Sheridan. |
| | | Silverbow. |
| | | Valley. |
| Nebraska | 75–79 | Banner |
| | | Boxbutte. |
| | | Boyd. |
| | | Brown. |
| | | Chase. |
| | | Cherry. |
| | | Cheyenne. |
| | | Dawes. |
| | | Deuel. |
| | | Frontier. |
| | | Garden. |
| | | Garfield. |
| | | Hayes. |
| | | Holt. |
| | | Keith. |
| | | Keyapaha. |
| | | Kimball. |
| | | Loup. |
| | | Morrill. |
| | | Perkins. |
| | | Rock. |
| | | Scotts Bluff. |
| | | Sheridan. |
| | | Sioux. |
| | 80–84 | Adams. |
| | | Antelope. |
| | | Boone. |
| | | Buffalo. |
| | | Butler. |
| | | Cedar. |
| | | Clay. |
| | | Colfax. |
| | | Cuming. |
| | | Custer. |
| | | Dawson. |
| | | Dixon. |
| | | Dodge. |
| | | Dundy. |
| | | Fillmore. |
| | | Franklin. |
| | | Furnas. |
| | | Gosper. |
| | | Greeley. |
| | | Hall. |
| | | Hamilton. |
| | | Harlan. |
| | | Hitchcock. |
| | | Howard. |
| | | Jefferson. |
| | | Kearney. |
| | | Knox. |
| | | Lincoln. |
| | | Madison. |
| | | Merrick. |
| | | Nance. |
| | | Nuckolls. |
| | | Phelps. |
| | | Pierce. |
| | | Platte. |
| | | Polk. |
| | | Redwillow. |
| | | Saline. |
| | | Saunders. |
| | | Seward. |
| | | Sherman. |
| | | Stanton. |
| | | Thayer. |
| | | Valley. |
| | | Wayne. |
| | | Webster. |
| | | Wheeler. |
| | | York. |
| | 85–89 | Burt. |
| | | Cass. |
| | | Dakota. |
| | | Douglas. |
| | | Gage. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Nebraska (continued). | 85–89 | Johnson. |
| | | Lancaster. |
| | | Nemaha. |
| | | Otoe. |
| | | Pawnee. |
| | | Richardson. |
| | | Sarpy. |
| | | Thurston. |
| | | Washington. |
| Nevada | 90–94 | Churchill. |
| | | Douglas. |
| | | Humboldt. |
| | | Lyon. |
| | | Ormsby. |
| | | Storey. |
| | | Washoe. |
| New Hampshire. (None.) | | |
| New Jersey | 95–99 | Burlington. |
| | | Camden. |
| | | Cumberland. |
| | | Gloucester. |
| | | Hunterdon. |
| | | Mercer. |
| | | Middlesex. |
| | | Monmouth. |
| | | Morris. |
| | | Salem. |
| | | Somerset. |
| | | Warren. |
| New Mexico | 85–89 | Mora. |
| | | San Miguel. |
| | | Taos. |
| | 90–94 | Rio Arriba. |
| | | San Juan. |
| | | Santa Fe. |
| | 95–99 | Bernalillo. |
| | | Dona Ana. |
| | | Sandoval. |
| | | Socorro. |
| | | Torrance. |
| | | Valencia. |
| New York | 100–104 | Allegany. |
| | | Cattaraugus. |
| | | Cayuga. |
| | | Chautauqua. |
| | | Chemung. |
| | | Erie. |
| | | Genesee. |
| | | Livingston. |
| | | Monroe. |
| | | Niagara. |
| | | Onondaga. |
| | | Ontario. |
| | | Orleans. |
| | | Schuyler. |
| | | Seneca. |
| | | Steuben. |
| | | Tioga. |
| | | Tompkins. |
| | | Wayne. |
| | | Wyoming. |
| | | Yates. |
| | 110–114 | Orange. |
| | | Ulster. |
| North Carolina | 105-109 | Alamance. |
| | | Buncombe. |
| | | Caswell. |
| | | Cherokee. |
| | | Clay. |
| | | Durham. |
| | | Graham. |
| | | Guilford. |
| | | Haywood. |
| | | Henderson. |
| | | Jackson. |
| | | McDowell. |
| | | Macon. |
| | | Madison. |
| North Carolina (continued). | 105–109 | Mitchell. |
| | | Orange. |
| | | Person. |
| | | Polk. |
| | | Rockingham. |
| | | Rutherford. |
| | | Swain. |
| | | Transylvania. |
| | | Yancey. |
| | 110–114 | Alexander. |
| | | Alleghany. |
| | | Ashe. |
| | | Burke. |
| | | Cabarrus. |
| | | Caldwell. |
| | | Catawba. |
| | | Chatham. |
| | | Cleveland. |
| | | Davisdon. |
| | | Davie. |
| | | Forsyth. |
| | | Franklin. |
| | | Gaston. |
| | | Granville. |
| | | Iredell. |
| | | Johnston. |
| | | Lee. |
| | | Lincoln. |
| | | Mecklenburg. |
| | | Montgomery. |
| | | Moore. |
| | | Randolph. |
| | | Rowan. |
| | | Stanly. |
| | | Stokes. |
| | | Surry. |
| | | Vance. |
| | | Wake. |
| | | Warren. |
| | | Watauga. |
| | | Wilkes. |
| | | Yadkin. |
| | 115 or over | Anson. |
| | | Richmond. |
| | | Union. |
| North Dakota | 80-84 | Adams. |
| | | Billings. |
| | | Bowman. |
| | | Burke. |
| | | Divide. |
| | | Dunn. |
| | | Hettinger. |
| | | McKenzie. |
| | | McLean. |
| | | Mercer. |
| | | Mountrail. |
| | | Morton. |
| | | Oliver. |
| | | Renville. |
| | | Stark. |
| | | Ward. |
| | | Williams. |
| | 85–89 | Barnes. |
| | | Benson. |
| | | Bottineau. |
| | | Burleigh. |
| | | Cass. |
| | | Cavalier. |
| | | Dickey. |
| | | Eddy. |
| | | Emmons. |
| | | Foster. |
| | | Golden Valley. |
| | | Grand Forks. |
| | | Griggs. |
| | | Kidder. |
| | | La Moure. |
| | | Logan. |
| | | McHenry. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| North Dakota (continued). | 85–89 | McIntosh. |
| | | Nelson. |
| | | Pembina. |
| | | Pierce. |
| | | Ramsey. |
| | | Ransom. |
| | | Richland. |
| | | Rolette. |
| | | Sargent. |
| | | Sheridan. |
| | | Steele. |
| | | Stutsman. |
| | | Towner. |
| | | Traill. |
| | | Walsh. |
| | | Wells. |
| Ohio | 95–99 | Adams. |
| | | Allen. |
| | | Ashland. |
| | | Athens. |
| | | Auglaize. |
| | | Belmont. |
| | | Brown. |
| | | Butler. |
| | | Carroll. |
| | | Champaign. |
| | | Clark. |
| | | Clermont. |
| | | Clinton. |
| | | Columbiana. |
| | | Coshocton. |
| | | Crawford. |
| | | Dark. |
| | | Defiance. |
| | | Delaware. |
| | | Erie. |
| | | Fairfield. |
| | | Fayette. |
| | | Franklin. |
| | | Fulton. |
| | | Gallia. |
| | | Greene. |
| | | Guernsey. |
| | | Hancock. |
| | | Hardin. |
| | | Harrison. |
| | | Henry. |
| | | Highland. |
| | | Hocking. |
| | | Holmes. |
| | | Huron. |
| | | Jackson. |
| | | Jefferson. |
| | | Knox. |
| | | Lawrence. |
| | | Licking. |
| | | Logan. |
| | | Lucas. |
| | | Madison. |
| | | Mahoning. |
| | | Marion. |
| | | Medina. |
| | | Meigs. |
| | | Mercer. |
| | | Miami. |
| | | Monroe. |
| | | Montgomery. |
| | | Morgan. |
| | | Morrow. |
| | | Muskingum. |
| | | Noble. |
| | | Ottawa. |
| | | Paulding. |
| | | Perry. |
| | | Pickaway. |
| | | Pike. |
| | | Portage. |
| | | Preble. |
| | | Putnam. |
| Ohio (continued) | 95–99 | Richland. |
| | | Ross. |
| | | Sandusky. |
| | | Scioto. |
| | | Seneca. |
| | | Shelby. |
| | | Stark. |
| | | Summit. |
| | | Tuscarawas. |
| | | Union. |
| | | Van Wert. |
| | | Vinton. |
| | | Warren. |
| | | Washington. |
| | | Wayne. |
| | | Williams. |
| | | Wood. |
| | | Wyandot. |
| | 100–104 | Ashtabula. |
| | | Cuyahoga. |
| | | Geauga. |
| | | Hamilton. |
| | | Lake. |
| | | Lorain. |
| | | Trumbull |
| Oklahoma | 85–89 | Adair. |
| | | Alfalfa. |
| | | Beaver. |
| | | Beckham. |
| | | Blaine. |
| | | Caddo. |
| | | Canadian. |
| | | Cherokee. |
| | | Cimarron. |
| | | Craig. |
| | | Custer. |
| | | Delaware. |
| | | Dewey. |
| | | Ellis. |
| | | Garfield. |
| | | Grant. |
| | | Harper. |
| | | Kay. |
| | | Kingfisher. |
| | | Kiowa. |
| | | Logan. |
| | | Major. |
| | | Mayes. |
| | | Noble. |
| | | Nowata. |
| | | Osage. |
| | | Ottawa. |
| | | Pawnee. |
| | | Payne. |
| | | Roger Mills. |
| | | Rogers. |
| | | Texas. |
| | | Tulsa. |
| | | Wagoner. |
| | | Washington. |
| | | Washita. |
| | | Woods. |
| | | Woodward. |
| | 90–94 | Cleveland. |
| | | Comanche. |
| | | Cotton. |
| | | Greer. |
| | | Harmon. |
| | | Jackson. |
| | | Oklahoma. |
| | | Tillman. |
| Oregon | 75–79 | Gilliam. |
| | | Morrow. |
| | | Umatilla. |
| | | Union. |
| | | Wallowa. |
| | 80–84 | Baker. |
| | | Crook. |
| | | Grant. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
|  | *Cents.* |  |
| Oregon (continued). | 80–84 | Klamath. |
|  |  | Malheur. |
|  |  | Sherman. |
|  |  | Wasco. |
|  |  | Wheeler. |
|  | 85–89 | Benton. |
|  |  | Clackamas. |
|  |  | Douglas. |
|  |  | Harney. |
|  |  | Jackson. |
|  |  | Lake. |
|  |  | Lane. |
|  |  | Linn. |
|  |  | Marion. |
|  |  | Polk. |
|  |  | Washington. |
|  |  | Yamhill. |
| Pennsylvania | 95–99 | Adams. |
|  |  | Armstrong. |
|  |  | Bedford. |
|  |  | Berks. |
|  |  | Blair. |
|  |  | Bucks. |
|  |  | Butler. |
|  |  | Center. |
|  |  | Chester. |
|  |  | Clarion. |
|  |  | Clearfield. |
|  |  | Clinton. |
|  |  | Colombia. |
|  |  | Cumberland. |
|  |  | Dauphin. |
|  |  | Delaware. |
|  |  | Franklin. |
|  |  | Fulton. |
|  |  | Huntingdon. |
|  |  | Indiana. |
|  |  | Jefferson. |
|  |  | Juniata. |
|  |  | Lancaster. |
|  |  | Lebanon. |
|  |  | Lehigh. |
|  |  | Lycoming. |
|  |  | Mifflin. |
|  |  | Montgomery. |
|  |  | Montour. |
|  |  | Northampton. |
|  |  | Northumberland. |
|  |  | Perry. |
|  |  | Philadelphia. |
|  |  | Schuylkill. |
|  |  | Snyder. |
|  |  | Union. |
|  |  | Washington. |
|  |  | Westmoreland. |
|  |  | York. |
|  | 100–104 | Allegheny. |
|  |  | Beaver. |
|  |  | Bradford. |
|  |  | Cambria. |
|  |  | Carbon. |
|  |  | Crawford. |
|  |  | Erie. |
|  |  | Fayette. |
|  |  | Greene. |
|  |  | Lawrence. |
|  |  | Luzerne. |
|  |  | Mercer. |
|  |  | Monroe. |
|  |  | Somerset. |
|  |  | Tioga. |
|  |  | Venango. |
| Rhode Island. (None.) |  |  |
| South Carolina | 115 or over | Abbeville. |
|  |  | Anderson. |
|  |  | Cherokee. |
|  |  | Greenville. |
| South Carolina (continued). | 115 or over | Greenwood. |
|  |  | Laurens. |
|  |  | Lexington. |
|  |  | Newberry. |
|  |  | Oconee. |
|  |  | Pickens. |
|  |  | Saluda. |
|  |  | Spartanburg. |
|  |  | Union. |
|  |  | York. |
| South Dakota | 80–84 | Aurora. |
|  |  | Brule. |
|  |  | Buffalo. |
|  |  | Butte. |
|  |  | Charles Mix. |
|  |  | Custer. |
|  |  | Douglas. |
|  |  | Fall River. |
|  |  | Gregory. |
|  |  | Hand. |
|  |  | Hyde. |
|  |  | Jerauld. |
|  |  | Lawrence. |
|  |  | Lyman. |
|  |  | Meade. |
|  |  | Pennington. |
|  |  | Sully. |
|  | 85–89 | Beadle. |
|  |  | Bonhomme. |
|  |  | Brookings. |
|  |  | Brown. |
|  |  | Campbell. |
|  |  | Clark. |
|  |  | Clay. |
|  |  | Codington. |
|  |  | Davison. |
|  |  | Day. |
|  |  | Deuel. |
|  |  | Edmunds. |
|  |  | Faulk. |
|  |  | Grant. |
|  |  | Hamlin. |
|  |  | Hanson. |
|  |  | Hutchinson. |
|  |  | Kingsbury. |
|  |  | Lake. |
|  |  | Lincoln. |
|  |  | McCook. |
|  |  | McPherson. |
|  |  | Marshall. |
|  |  | Miner. |
|  |  | Minnehaha. |
|  |  | Moody. |
|  |  | Potter. |
|  |  | Roberts. |
|  |  | Sanborn. |
|  |  | Spink. |
|  |  | Turner. |
|  |  | Union. |
|  |  | Walworth. |
|  |  | Yankton. |
| Tennessee | 95–99 | Bedford. |
|  |  | Cannon. |
|  |  | Carroll. |
|  |  | Cheatham. |
|  |  | Clay. |
|  |  | Coffee. |
|  |  | Crockett. |
|  |  | Davidson. |
|  |  | Dekalb |
|  |  | Dickson. |
|  |  | Dyer. |
|  |  | Franklin. |
|  |  | Gibson. |
|  |  | Giles. |
|  |  | Haywood. |
|  |  | Henry. |
|  |  | Hickman. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Tennessee (continued). | 95-99 | Humphreys. |
| | | Jackson. |
| | | Lake. |
| | | Lauderdale. |
| | | Lawrence. |
| | | Lincoln. |
| | | Macon. |
| | | Madison. |
| | | Marshall. |
| | | Maury. |
| | | Montgomery. |
| | | Moore. |
| | | Obion. |
| | | Overton. |
| | | Pickett |
| | | Putnam. |
| | | Robertson. |
| | | Rutherford. |
| | | Smith. |
| | | Stewart. |
| | | Sumner. |
| | | Trousdale. |
| | | Weakley. |
| | | White. |
| | | Williamson. |
| | | Wilson. |
| | 100-104 | Anderson. |
| | | Bledsoe. |
| | | Blout. |
| | | Bradley. |
| | | Carter. |
| | | Claiborne. |
| | | Cocke. |
| | | Grainger. |
| | | Greene. |
| | | Grundy. |
| | | Hamblen. |
| | | Hamilton. |
| | | Hancock. |
| | | Hawkins. |
| | | James. |
| | | Jefferson. |
| | | Johnson. |
| | | Knox. |
| | | Loudon. |
| | | McMinn. |
| | | Marion. |
| | | Meigs. |
| | | Monroe. |
| | | Polk. |
| | | Rhea. |
| | | Roane. |
| | | Sequatchie. |
| | | Sevier. |
| | | Sullivan. |
| | | Unicoi. |
| | | Union. |
| | | Van Buren. |
| | | Warren. |
| | | Washington. |
| Texas | 90-94 | Armstrong. |
| | | Briscoe. |
| | | Carson. |
| | | Castro. |
| | | Collingsworth. |
| | | Dallam. |
| | | Deaf Smith. |
| | | Gray. |
| | | Hale. |
| | | Hansford. |
| | | Hartley. |
| | | Hemphill. |
| | | Hutchinson. |
| | | Lipscomb. |
| | | Moore. |
| | | Ochiltree. |
| | | Oldham. |
| | | Parmer. |
| | | Potter. |
| | *Cents.* | |
| Texas (continued) | 90-94 | Randall. |
| | | Roberts. |
| | | Sherman. |
| | | Swisher. |
| | | Wheeler. |
| | 95-99 | Archer. |
| | | Baylor. |
| | | Bell. |
| | | Bosque. |
| | | Burnet. |
| | | Clay. |
| | | Coryell. |
| | | Foard. |
| | | Gillespie. |
| | | Hamilton. |
| | | Hardeman. |
| | | Haskell. |
| | | Jones. |
| | | Kerr. |
| | | Knox. |
| | | McLennan. |
| | | Wichita. |
| | | Wilbarger. |
| | | Young. |
| | 100-104 | Collin. |
| | | Cooke. |
| | | Dallas. |
| | | Denton. |
| | | Fannin. |
| | | Grayson. |
| | | Montague. |
| | | Parker. |
| | | Tarrant. |
| | | Wise. |
| Utah | 75-79 | Boxelder. |
| | | Cache. |
| | | Davis. |
| | | Juab. |
| | | Millard. |
| | | Rich. |
| | | Tooele. |
| | 80-84 | Beaver. |
| | | Emery. |
| | | Piute. |
| | | Sanpete. |
| | | Sevier. |
| | | Wayne. |
| | 85-89 | Carbon. |
| | | Duchesne. |
| | | Morgan. |
| | | Salt Lake. |
| | | Summit. |
| | | Uinta. |
| | | Utah. |
| | | Wasatch. |
| | | Weber. |
| | | Garfield. |
| | | Iron. |
| | | Washington. |
| Vermont. (None.) | | |
| Virginia | 95-99 | Alexandria. |
| | | Clarke. |
| | | Culpeper. |
| | | Essex. |
| | | Fairfax. |
| | | Fauquier. |
| | | Frederick. |
| | | Greene. |
| | | King George. |
| | | Lancaster. |
| | | Loudoun. |
| | | Madison. |
| | | Middlesex. |
| | | Northumberland. |
| | | Orange. |
| | | Page. |
| | | Prince William. |
| | | Rappahannock. |
| | | Richmond. |

| State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|
| | *Cents.* | |
| Virginia (continued) | 95–99 | Shenandoah. |
| | | Spotsylvania. |
| | | Stafford. |
| | | Warren. |
| | | Westmoreland. |
| | 100–104 | Albemarle. |
| | | Amelia. |
| | | Amherst. |
| | | Appomattox. |
| | | Augusta. |
| | | Bedford. |
| | | Botetourt. |
| | | Buckingham. |
| | | Campbell. |
| | | Caroline. |
| | | Charles City. |
| | | Chesterfield. |
| | | Cumberland. |
| | | Fluvanna. |
| | | Franklin. |
| | | Gloucester. |
| | | Goochland. |
| | | Hanover. |
| | | Henrico. |
| | | King and Queen. |
| | | King William. |
| | | Lee. |
| | | Louisa. |
| | | Nelson. |
| | | New Kent. |
| | | Powhatan. |
| | | Prince Edward. |
| | | Roanoke. |
| | | Rockbridge. |
| | | Rockingham. |
| | | Russell. |
| | | Scott. |
| | | Smyth. |
| | | Washington. |
| | 110–114 | Alleghany. |
| | | Bath. |
| | | Bland. |
| | | Brunswick. |
| | | Carroll. |
| | | Charlotte. |
| | | Craig. |
| | | Dinwiddie. |
| | | Floyd. |
| | | Giles. |
| | | Grayson. |
| | | Halifax. |
| | | Henry. |
| | | Highland. |
| | | Lunenburg. |
| | | Mecklenburg. |
| | | Montgomery. |
| | | Nottoway. |
| | | Patrick. |
| | | Pittsylvania. |
| | | Prince George. |
| | | Pulaski. |
| | | Tazewell. |
| | | Wythe. |
| Washington | 75–79 | Adams. |
| | | Asotin. |
| | | Benton. |
| | | Columbia. |
| | | Douglas. |
| | | Ferry. |
| | | Franklin. |
| | | Garfield. |
| | | Grant. |
| | | Lincoln. |
| | | Pend Oreille. |
| | | Spokane. |
| | | Stevens. |
| | | Walla Walla. |
| | | Whitman. |
| Washington (continued). | 80–84 | Chelan. |
| | | Kittitas. |
| | | Klickitat. |
| | | Okanogan. |
| | | Yakima. |
| West Virginia | 95–99 | Berkeley. |
| | | Brooke. |
| | | Hancock. |
| | | Jefferson. |
| | | Marshall. |
| | | Morgan. |
| | | Ohio. |
| | 100–104 | Cabell. |
| | | Hampshire. |
| | | Hardy. |
| | | Jackson. |
| | | Lincoln. |
| | | Mason. |
| | | Mineral. |
| | | Monongalia. |
| | | Pleasants. |
| | | Putnam |
| | | Tyler. |
| | | Wayne. |
| | | Wetzel. |
| | | Wirt. |
| | | Wood. |
| | 105–109 | Barbour. |
| | | Braxton. |
| | | Calhoun. |
| | | Doddridge. |
| | | Gilmer. |
| | | Grant. |
| | | Greenbrier. |
| | | Harrison. |
| | | Kanawha. |
| | | Lewis. |
| | | Marion. |
| | | Mercer. |
| | | Monroe. |
| | | Pendleton. |
| | | Pocahontas. |
| | | Preston. |
| | | Ritchie. |
| | | Roane. |
| | | Summers. |
| | | Taylor. |
| | | Upshur. |
| Wisconsin | 85–89 | Buffalo. |
| | | Jackson. |
| | | La Crosse. |
| | | Monroe. |
| | | Pepin. |
| | | Trempealeau. |
| | | Vernon. |
| | 90–94 | Barron. |
| | | Brown. |
| | | Burnett. |
| | | Calumet. |
| | | Chippewa. |
| | | Clark. |
| | | Columbia. |
| | | Crawford. |
| | | Dane. |
| | | Dodge. |
| | | Door. |
| | | Dunn. |
| | | Eu Claire. |
| | | Fond du Lac. |
| | | Grant. |
| | | Green Lake. |
| | | Iowa. |
| | | Jefferson. |
| | | Juneau. |
| | | Kewaunee. |
| | | Lafayette. |
| | | Marathon. |
| | | Oconto. |

| State. | Approximate farm price, per bushel. | Counties. | State. | Approximate farm price, per bushel. | Counties. |
|---|---|---|---|---|---|
| | *Cents.* | | | *Cents.* | |
| Wisconsin (continued). | 90-94 | Outagamie.<br>Pierce.<br>Polk.<br>Richland.<br>St. Croix.<br>Sauk.<br>Shawano.<br>Washburn.<br>Waupaca.<br>Winnebago. | Wyoming.......... | 70-74 | Lincoln. |
| | | | | 75-79 | Goshen.<br>Laramie.<br>Platte. |
| | | | | 80-84 | Bighorn.<br>Campbell.<br>Crook.<br>Hot Springs.<br>Johnson.<br>Park.<br>Sheridan.<br>Washakie.<br>Weston. |
| | 95-99 | Manitowoc<br>Sheboygan.<br>Washington.<br>Waukesha. | | | |

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UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 595**

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ October 11, 1917

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# WINTER WHEAT IN THE GREAT PLAINS AREA:

## RELATION OF CULTURAL METHODS TO PRODUCTION.

By E. C. Chilcott, *Agriculturist in Charge*, John S. Cole, *Agriculturist*, and J. B. Kuska, *Assistant, Office of Dry-Land Agriculture*.[1]

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| Climatic conditions | 3 |
| General plan of the investigations | 4 |
| Comparison of cultural methods | 7 |
| Results at the several stations | 10 |
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| Comparison of winter wheat with spring wheat | 32 |
| Conclusions | 34 |

## INTRODUCTION.

This bulletin contains a study of the yields of winter wheat obtained under various methods of seed-bed preparation at 13 field stations in the Great Plains region.

The study as here made shows the effect of the cropping and cultivation of the land in only the one year preceding the growth of the winter wheat. A study of the cost of production by each of the methods under trial and the resulting profit or loss is also given. There is also presented for comparison the average yields and the resulting profits or losses from spring wheat grown by the same methods at the same stations for the same years.

Results are presented from an aggregate of 75 station years, involving an aggregate of 1,137 plat years. By "station year" is meant one year at one station; by "plat year" is meant one plat at one station for one year.

Such a mass of material furnishes an infinite amount of detail for study, but it is the purpose of this bulletin to consider only the broader bearings and more obvious and important phases of the work rather than a study of the details.

This bulletin, dealing with only one crop, does not afford a measure for judging the agricultural possibilities for other crops of any section of the Great Plains area. The Office of Dry-Land Agriculture of the United

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[1] For a list of members of the scientific staff of the Office of Dry-Land Agriculture, cooperating stations, etc., see the second page of the cover.

Note.—This bulletin is intended for all who are interested in the agricultural possibilities of the Great Plains area.

States Department of Agriculture began field work in the investigation of methods of crop production in this area in 1906. The work begun at that time has been constantly added to until 24 stations were in operation in 1916. Data from only 13 of these stations are here presented; those that have been operated less than four years are not included.

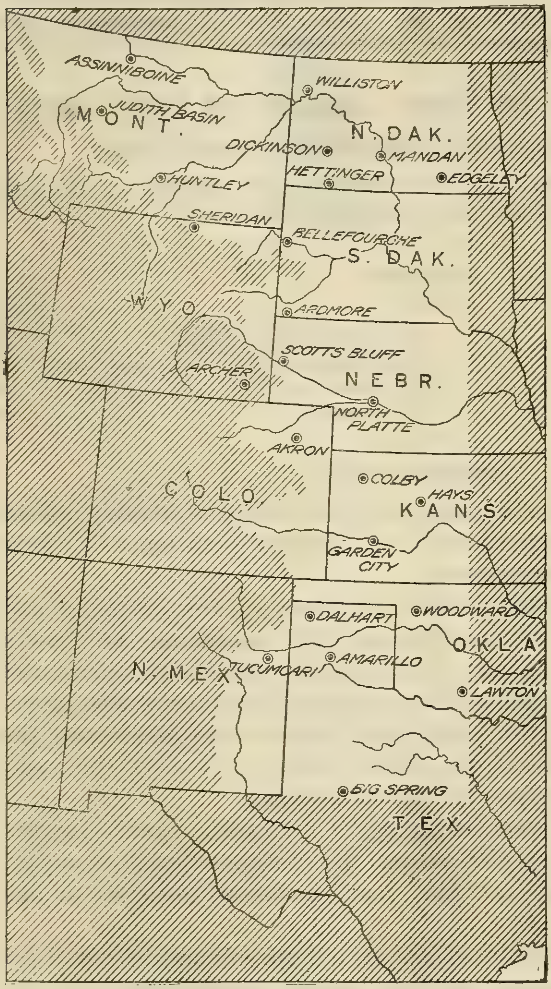

FIG. 1.—Sketch map of the Great Plains area, which includes parts of ten States and consists of about 400,000 square miles of territory. Its western boundary is indicated by the 5,000-foot contour. The location of each field station within the area is shown by a dot within a circle (⊙).

The method of work adopted was that of raising the different crops both in different combinations or systems of rotation and under different methods of cultivation in systems of continuous cropping. In no case have rotations of more than six years in length been used. Those of even this length have been tried only with sod crops. More of the work has been done with 3-year and 4-year rotations.

## AREA INCLUDED IN THESE INVESTIGATIONS.

The area covered by these investigations is shown in figure 1 and consists of about 400,000 square miles of territory. It includes the western portions of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, and the eastern portions of Montana, Wyoming, Colorado, and New Mexico. As no varieties of winter wheat have yet been found which are able to survive the winter in North Dakota, this crop is not included in the work at the North Dakota stations. The fact that limited rainfall is the determining factor in crop production is responsible for a general uniformity in conditions throughout the area. There is, however, a wide range of soil, climatic conditions, and altitude. The lowest station where winter wheat is grown is Hays, Kans., with an altitude of 2,050 feet, and the highest is Archer, Wyo., with an altitude of 6,012 feet. The length of the growing season for winter wheat is naturally much the same throughout the area, but there is a variation of approximately a month to six weeks in the respective dates of seeding and harvesting. The northern stations seed somewhat earlier than the southern, while the southern stations harvest earlier than the northern.

## CLIMATIC CONDITIONS.

The Great Plains area is characterized by a varying amount of annual and seasonal precipitation, with very uncertain distribution. Years of relatively high precipitation with favorable distribution may be followed by years of relatively low precipitation with very unfavorable distribution. It may be said that the uncertainty of the distribution rather than the total amount of rainfall received is the factor that makes crop production hazardous. In connection with this work, complete climatic data have been obtained. It is not practicable, however, to present them in this publication. Table I shows the minimum, maximum, and average annual and seasonal rainfall and the seasonal evaporation at each station for the years for which the yields are here reported. By seasonal is meant the precipitation or evaporation for the period between the average time of growth beginning in the spring and the average time of harvesting. No attempt is made here to show any of the other climatic factors or the amount of water already in the soil at seeding time, any of which might have an important influence on yields. The annual precipitation as here given is not the average as determined from the complete record, but is the average annual precipitation of the years whose results are under study

TABLE I.—*Annual and seasonal precipitation and seasonal evaporation at thirteen stations in the Great Plains area.*[1]

| Station. | Altitude [2] (feet). | Precipitation [3] (inches). | | | | | | Seasonal evaporation [4] (inches). | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Annual. | | | Seasonal. | | | | | |
| | | Minimum. | Maximum. | Average. | Minimum. | Maximum. | Average. | Minimum. | Maximum. | Average. |
| Judith Basin | 4,228 | 14.96 | 23.78 | 18.31 | 6.50 | 11.06 | 9.03 | 18.544 | 26.273 | 21.205 |
| Huntley | 3,000 | 11.92 | 17.54 | 13.79 | 5.00 | 11.83 | 7.62 | 18.486 | 21.799 | 20.175 |
| Belle Fourche | 2,950 | 6.64 | 21.02 | 13.96 | 1.92 | 15.38 | 8.04 | 18.388 | 33.906 | 25.415 |
| Ardmore | 3,557 | 13.23 | 30.41 | 17.66 | 6.93 | 20.34 | 11.14 | 19.555 | 28.140 | 24.828 |
| Archer | 6,012 | 11.77 | 18.32 | 14.16 | 4.64 | 10.16 | 7.12 | 20.056 | 27.320 | 24.319 |
| Scottsbluff | 3,950 | 9.95 | 23.58 | 15.44 | 6.75 | 10.78 | 8.31 | 23.006 | 27.620 | 25.556 |
| North Platte | 3,000 | 11.18 | 34.85 | 19.31 | 5.61 | 23.52 | 11.09 | 24.621 | 35.255 | 29.620 |
| Akron | 4,600 | 13.74 | 25.00 | 18.22 | 6.60 | 14.17 | 9.67 | 21.796 | 33.114 | 28.449 |
| Hays | 2,050 | 15.59 | 32.90 | 21.45 | 3.87 | 16.58 | 10.41 | 22.402 | 41.317 | 31.333 |
| Garden City | 2,900 | 9.70 | 26.51 | 18.05 | 5.01 | 10.95 | 7.51 | 29.802 | 39.354 | 35.144 |
| Dalhart | 4,000 | 13.69 | 22.81 | 16.67 | 4.54 | 14.86 | 8.21 | 31.854 | 41.002 | 37.813 |
| Amarillo | 3,676 | 10.69 | 27.80 | 18.61 | 5.03 | 11.49 | 7.11 | 29.647 | 40.704 | 36.130 |
| Tucumcari | 4,194 | 10.89 | 22.24 | 17.12 | 2.83 | 11.07 | 7.03 | 32.285 | 42.405 | 37.139 |

[1] The years covered are the same as for the data shown in the other tables for each station.

[2] The altitude given is for the field where the work was done and is based in most cases on that of the nearest town.

[3] The seasonal rainfall is the amount from Apr. 1 to July 31 for stations north of and including Akron. For stations south of Akron it is the amount between Mar. 1 and June 30.

[4] The evaporation is figured from April 1 to July 31.

## GENERAL PLAN OF THE INVESTIGATIONS.

The same variety of winter wheat is used on all plats at a station during any one year. The intention is to use the best variety that is available for general use. Changes are made only when seed breeding, selection, or varietal testing make available for general use a better variety. No attempt is made to use the same variety at different stations. The only varieties that have been used, however, have been strains of Turkey and Kharkof. The rate, time, and manner of seeding are the same for all plats at a station in any one year. As compared with more humid sections, the seeding is light, the usual rate being 3 pecks per acre. All seeding is done with a drill, the rows being spaced from 6 to 8 inches apart, depending upon the locality. In different places different styles of drills are used.

At each station the plats are one-tenth acre in size. Their dimensions are 2 by 8 rods. Along their larger dimension the plats are separated by bare alleys 4 feet in width. The ends of the plats are separated by roads 20 feet wide.

There are as many field plats devoted to each rotation as there are years required to complete the cycle of the rotation. Each crop in a rotation is thus grown each year.

Each rotation is given a number, and each plat within the rotation is designated by a letter.

In addition to rotations or different combinations of crops and cultural methods, there is at each station a series of plats continuously cropped by different methods to each of the important crops. With each crop in this series two plats, known as C and D, are alternately cropped and summer tilled.

In the present study a table is presented for each station. The first part of such table shows the yields that have been obtained in each year by each of the different methods under which winter wheat has been grown, considering only the variations in the one year preceding the crop. The previous crop whose stubble was treated as specified is also shown. Where more than one plat has been under the same treatment for the previous year, only the average yield of the whole number of plats so grown is given. Column 2 of the table shows the number of plats so averaged. The succeeding columns need no explanation, as they show the yields for each year as indicated and the averages of each method for the whole period of years. In the last column, where the average appears under the heading "Average," the calculation is from the left. The averages of the different methods of treatment are the averages of the whole number of plats that entered into their composition. For a rough comparison of seasons the bottom line of the first half of the table gives the averages of all plats for each year, the average of the yearly yields appearing in the last column to the right. (See Tables V to XVIII.)

As here presented, the treatment of the land is specified as early fall plowed, late fall plowed, subsoiled, listed, disked, green manured, and summer tilled. Under these headings are subdivisions to show the preceding crop. At the Judith Basin and Huntley stations, on account of the lateness of the harvest, the plats in the "Early fall plowed" and the "Late fall plowed" columns are plowed at the same time, the former deep, 8 inches, and the latter shallow, about 4 inches.

Where winter wheat follows winter wheat, the system has been that of continuous cropping.

Early fall plowing is done as early as practicable after harvest and to a good depth, the standard being set at 8 inches. The ground after being plowed is given sufficient cultivation with the disk and harrow, if necessary, to form a good seed bed. On one plat which is continuously cropped to winter wheat at each station late fall plowing is shallow, only about 4 inches, and is given a minimum of cultivation.

Subsoiling is done on land continuously cropped to winter wheat. The treatment of the plat that appears at some stations under this heading is the same as the treatment of the plat that appears under "Early fall plowed," except that it is subsoiled. At the time of plowing, a subsoiler is run in each alternate furrow to an additional depth of 6 to 8 inches, making a total depth of about 14 inches. This usually is done two years in succession and then omitted for two years.

The plat that appears at some stations under the heading "Listed," following winter wheat, is continuously cropped to winter wheat. After harvest this plat is furrowed out with the lister instead of being plowed. It is worked down level and the seed bed prepared without the use of the plow.

The plats on disked corn ground are all in rotation with other crops. Both 3-year and 4-year rotations comprise this series. The other crops may be oats, barley, green manure, or potatoes. In some rotations summer tillage replaces one of the crops.

Where winter wheat is grown after a green-manure crop, the system is that of a 4-year rotation in which there is a row crop and one of the small grains. In some of the 4-year rotations summer tillage is substituted for the second small-grain crop. Rye and field peas are used as green-manure crops. At Hays, Garden City, Dalhart, and Amarillo cowpeas were used instead of field peas during the first years.

The method of summer tillage practiced is of an intensive type. The land lies fallow for a year. It is kept clear of weeds and as far as practicable a mulch is maintained on it during the summer preceding the seeding of the wheat. In some cases it is necessary to plow the land more than once during the period, in order either to maintain a surface receptive to water and resistant to blowing or to prevent the growth of weeds. As practiced, this is an expensive system of production. Experiments are under way to determine the most economical method of summer tillage. The indications are that a less intensive method than that practiced in the work here reported will give practically as good returns.

The yields given in these tables begin with the second year of crop production at each station. The first year's crop is produced on land uniform in its treatment.

Where an entire crop has been lost by hail or other agency that could not possibly be overcome by cultivation, the year is not counted in computing averages. Such failures must, of course, enter into the final results of agricultural endeavor. They are, however, of such uncertain occurrence that the series of years here considered is too short to permit an attempt to establish their normal frequency for any locality. This is in effect what would be done by including them in averages. It is believed that less error is introduced by recognizing their occurrence and excluding them from averages. When the loss of a crop is due to conditions that might possibly have been overcome by cultural practices, a zero yield for that year is included in the calculations.

Embodying the basic data given in Tables II, III, and IV, the second part of the table for each station has been compiled. In this are brought together in summary form the yields detailed in the first part of such table. The value of the average yields thus obtained is calculated and given, together with a computation of the cost of production. The last line of the table gives the profit or loss resulting from the production of winter wheat by the method stated. Loss is indicated by the minus sign. In this second part of each table there are two general headings, "Tillage treatment" and "Previous crop." Under the first heading the plats are grouped entirely by treatment without considering the previous crop. Under the second heading treatment is not considered, and the grouping is entirely governed by the crop immediately preceding the winter wheat. This really makes two tables combined in one, with subdivisions common to both. (See Tables V to XVIII.)

Some of the rotations are calculated to conserve or increase the fertility of the soil, while others may perhaps deplete it. In the present stage of the work, the effects of rotations as units are greatly overshadowed by the effects of the cropping and cultivation of a single year. This is due to the fact that the controllable factors are the water supply, the physical condition of the seed bed, and a certain recognized, if not understood, effect of the crop immediately preceding. Uniformity in these factors is largely restored by the cultivation or cropping of a single season. After a careful study of the data, it seemed advisable two years ago to prepare a series of bulletins covering the results relating to a single crop as determined by the treatment of the land in only the one year immediately preceding the growth of that crop. Such a series of bulletins was published, but owing to the comparatively small amount of data on winter wheat available at that time, this crop was not included. The addition of the results of the two years that have since elapsed now warrants a publication of the same character relating to winter wheat.

## COMPARISON OF CULTURAL METHODS.

The methods under study vary a great deal in the labor involved and in the consequent cost of production by each method. Table IV has therefore been compiled in order to show the average cost by each of the methods under study. These data have been prepared from the records of 10 representative stations, and an average of the records of 6.7 years at each station has been used in preparing it. This is equivalent to a record of 67 years at one station. An accurate record has been kept of all the farm operations performed in the various methods under trial. These have been averaged for the 10 stations. The amount of work required for some methods of treatment varies with the season and with the soil, and the expense of some operations varies with the soil. The amount of labor performed under each of the methods was neither more nor less than that which the man in charge believed to be necessary to bring about the results sought.

In computing the cost of the various operations a fixed wage of $2 a day for a man and $1 a day for a horse was adopted. This may be above or below the actual labor cost in any particular locality, but it is believed to be a fair average and one that will afford a profitable market to the farmer for his labor. The time required of men and teams to cover a given acreage in each of the several farm operations obviously varies with soil and other conditions. The average shown in Table II has been determined from the actual experience of a large number of men connected with these investigations, experience that has extended over a wide range of conditions and many years of time.

The factors included in the cost of production are calculated on an acre basis for each of the separate operations performed, beginning with the preparation of the land and ending with the harvesting and shocking of the grain. To these items are added the cost of seed at 75 cents per acre, interest and taxes on the land investment, calculated at 8 per cent on a valuation of $20 per acre, and the deterioration and repairs of the binder at 15 cents per acre. No allowance is made for the deterioration of other farm equipment, as it is believed that the wages allowed for men and teams are sufficient to cover this item for the remainder of the equipment. The above-mentioned items are fixed charges per acre—that is, they do not vary greatly with the yield per acre except for the item of twine—but this variation is not sufficient to affect materially the relative total cost of production under the several methods.

Table II shows the cost per acre, based upon what is considered an average day's work for each of the farm operations involved at the above-mentioned wage. As before stated, the type of soil and seasonal conditions will determine to a certain extent the labor requirement and the consequent cost per acre.

TABLE II.—*Average cost per acre[1] of the farm operations involved in growing winter wheat in the Great Plains area.*

[The wage scale assumed is $2 per day for each man and $1 per day for each horse.]

| Operation. | Force employed. | | Day's work. | Item cost. | Cost per acre. |
|---|---|---|---|---|---|
| | Men. | Horses. | | | |
| | | | *Acres.* | | |
| Plowing | 1 | 4 | 3½ | | $1.71 |
| Disking | 1 | 4 | 8 | | .75 |
| Harrowing | 1 | 4 | 35 | | .17 |
| Subsoiling | 1 | 3 | 3½ | | 1.43 |
| Drilling | 1 | 4 | 15 | | .40 |
| Cultivating | 1 | 4 | 16 | | .38 |
| Listing | 1 | 4 | 10 | | .60 |
| Harvesting: | | | | | |
| Cutting and binding | 1 | 4 | 15 | $0.40 | .93 |
| Shocking | 1 | | | .13 | |
| Twine | | | | .25 | |
| Binder wear and repair | | | | .15 | |

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[1] The cost of thrashing is not included in the cost per acre, but it is estimated at 10 cents per bushel and deducted from the price of 80 cents in the granary, thus giving a value of 70 cents per bushel in the shock.

The average farm price of wheat used in these computations is based on the data given in Table III, furnished by the Bureau of Crop Estimates of the United States Department of Agriculture. The four States of Kansas, Nebraska, North Dakota, and South Dakota were selected, because their extensive wheat production has given them established market prices which are not greatly influenced by local conditions.

TABLE III.—*Average price[1] of wheat at the farm granary for ten years in four States of the Great Plains area.*

[The quotations are given in cents per bushel. Those for the year 1914 are for the date of Nov. 1; in other years Dec. 1 is taken as the date.]

| Year. | North Dakota. | South Dakota. | Nebraska. | Kansas. | Average. | Year. | North Dakota. | South Dakota. | Nebraska. | Kansas. | Average. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1905 | 69 | 67 | 66 | 71 | 68¼ | 1911 | 89 | 91 | 87 | 91 | 89½ |
| 1906 | 63 | 61 | 57 | 58 | 59¾ | 1912 | 69 | 69 | 69 | 74 | 70¼ |
| 1907 | 87 | 89 | 79 | 82 | 84¼ | 1913 | 73 | 71 | 71 | 79 | 73½ |
| 1908 | 92 | 92 | 84 | 88 | 89 | 1914 | 97 | 90 | 92 | 94 | 94¼ |
| 1909 | 92 | 90 | 89 | 96 | 91¾ | | | | | | |
| 1910 | 90 | 89 | 80 | 84 | 85¾ | Average | 82 | 81 | 77 | 82 | 80½ |

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[1] The figures in this table are the same as those used in Bulletin No. 214, "Spring Wheat in the Great Plains Area," published by the Office of Dry-Land Agriculture in 1915. The table has not been revised to include 1915 and 1916 because the prices during these two years have been largely determined by the abnormal conditions occasioned by the European war.

As given in Table III, the average farm price of wheat on December 1 for the 10 years preceding 1915 has been, in round numbers, 80 cents per bushel. It costs about 10 cents per bushel to take the grain from the shock, thrash it, and put it in the granary on the farm. This cost per bushel does not vary greatly with the yield and is therefore a fixed price per bushel instead of a fixed price per acre, as is the case with the other costs of production. The relative profits of producing winter wheat under the different methods can therefore best be determined by finding the difference between the fixed cost per acre and the value per acre of the grain at the point where the fixed cost per acre ends, which, as before stated, is when the grain is in the shock. Knowing that the average farm value of winter wheat in the granary is 80 cents per bushel and that it costs 10 cents per bushel to take it from the shock, thrash it, and put it in the granary, it is obvious that it would be worth 70 cents per bushel in the shock. This valuation of 70 cents per bushel has therefore been used as a basis for calculating the relative crop values, costs, and profits per acre of the various methods under trial.

TABLE IV.—*Cost per acre of producing winter wheat in the shock in the Great Plains area, showing averages of data for ten stations.*

| Method of preparation. | Number of operations. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Plowing. | Harrowing. | Disking. | Subsoiling. | Listing. | Drilling. | Leveling.[1] | Cultivating. |
| Disked corn | ........ | 0.5 | 1.3 | ........ | ........ | ........ | ........ | ........ |
| Listed | ........ | ........ | ........ | ........ | 1 | ........ | 1 | ........ |
| Late fall plowed | 1 | 1.1 | .2 | ........ | ........ | ........ | ........ | ........ |
| Early fall plowed | 1 | 1.7 | 1.7 | ........ | ........ | ........ | ........ | ........ |
| Subsoiled | 1 | 1.7 | 1.7 | 0.5 | ........ | ........ | ........ | ........ |
| Summer tilled | 1.5 | 5.8 | 3.8 | ........ | ........ | ........ | ........ | 1 |
| Green manured: | | | | | | | | |
| With rye[2] | 2 | 4.8 | 3.6 | ........ | ........ | 1 | ........ | .5 |
| With peas[3] | 2 | 4.8 | 3.6 | ........ | ........ | 1 | ........ | .5 |

| Method of preparation. | Cost of preparation. | Cost per acre. | | | Interest and taxes. | Total cost of production. | |
|---|---|---|---|---|---|---|---|
| | | Seed. | Drilling. | Harvesting. | | Per acre. | In bushels, at 70 cents per bushel. |
| Disked corn land | $0.57 | $0.75 | $0.40 | $0.93 | $1.60 | $4.25 | 6.1 |
| Listed | 1.75 | .75 | .40 | .93 | 1.60 | 5.03 | 7.2 |
| Late fall plowed | 1.97 | .75 | .40 | .93 | 1.60 | 5.65 | 8.1 |
| Early fall plowed | 2.64 | .75 | .40 | .93 | 1.60 | 6.32 | 9.0 |
| Subsoiled | 3.25 | .75 | 40 | .93 | 1.60 | 7.03 | 10.0 |
| Summer tilled | 5.36 | .75 | .40 | 93 | 3.20 | 10.64 | 15.2 |
| Green manured: | | | | | | | |
| With rye.[2] | 7.18 | .75 | .40 | .93 | 3.20 | 12.46 | 17.8 |
| With peas[3] | 10.18 | .75 | .40 | .93 | 3.20 | 15.46 | 22.1 |
| Average cost of green manuring | ........ | ........ | ........ | ........ | ........ | 13.96 | 19.9 |

[1] The cost of leveling listed ground for seeding is estimated at 75 cents per acre.
[2] The cost of rye for seeding 1 acre is estimated at $1.
[3] The cost of peas for seeding 1 acre is estimated at $4.

In conformity with the foregoing explanation, Table IV gives in detail the cost of producing winter wheat in the shock, expressed in dollars and cents and in bushels per acre at 70 cents per bushel. These prices are used as a working basis and are not offered as being exact. It is fully realized that the price of any or all factors used in obtaining them may vary locally from the fixed price assumed.

## RESULTS AT THE SEVERAL STATIONS.

Accompanying the discussion of each station is a very brief description of the soil, with particular reference to its depth and its water-holding capacity. Only such information is given as is necessary to understand fully the interpretation of the results.

### JUDITH BASIN FIELD STATION.

The field station at Moccasin, Mont., in the Judith Basin, is located on a heavy clay soil of limestone origin. The soil is apparently very rich in available fertility. It is underlain at a depth of approximately 3 feet by a limestone gravel that is closely cemented with lime materials. The gravel subsoil, which extends to a depth of about 30 feet, is practically free from soil. While it is so closely cemented that it does not unduly drain the soil, it is not of a character that allows the storage of available water or the development of roots within it. Gravel in the surface soil interferes with the taking of samples satisfactory for the study of soil moisture. Enough has been done, however, to make it certain that the supply of water that can be stored in this soil is limited. This shallowness of the soil and consequent limitation of the quantity of water that can be stored in it and recovered by the crop makes the crop dependent in large part upon the rains that fall while it is growing.

The first winter wheat raised at the station was the crop of 1909, which was all on summer-tilled land. The first crop which shows results from different methods of preparation is that of 1910.

In the period under study, there has been one failure of winter wheat, the crop of 1916 being lost by winterkilling. In 1912 the crop was badly damaged by a hailstorm that entirely destroyed the spring-sown grains.

The highest average yield, 25.7 bushels per acre, has been obtained from summer tillage. The yields from summer tillage have been the highest every year except in 1910. The next highest average yield, 24.4 bushels, was secured after green-manure crops. The yields after green manure have been higher than from any other method, except summer tillage, every year except in 1912. Since 1914, when the practice of seeding on disked corn ground was begun, this method has outyielded all others except green manuring and summer tillage. During this period, the yields after summer tillage have averaged 5.5 bushels greater than on disked corn ground.

The yields obtained from deep plowing, deep plowing and subsoiling, and the shallow plowing of winter-wheat stubble have shown only very small differences. Listing has averaged approximately 1 bushel per acre less than plowing. The highest average yield from any of these methods is 6.1 bushels less than after green manure and 7.4 bushels less than from summer tillage. During the three years that seeding on disked corn ground has been practiced the yields from this method have averaged 6.3 bushels higher than any of the other continuous-cropping methods used.

TABLE V.—*Yields and cost of production of winter wheat by different methods at the Judith Basin Field Station, 1910 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | [a] 1916 | Average. |
| Deep fall plowed: Winter wheat | 1 | 24.0 | 23.5 | 12.2 | 23.2 | 16.3 | 28.5 | 0 | 18.2 |
| Shallow fall plowed: Winter wheat | 1 | 23.8 | 22.0 | 13.2 | 25.5 | 16.3 | 25.0 | 0 | 18.0 |
| Listed: Winter wheat | 1 | 21.7 | 22.3 | 10.8 | 24.3 | 20.1 | 21.1 | 0 | 17.2 |
| Subsoiled: Winter wheat | 1 | 23.2 | 22.4 | 12.5 | 26.2 | 15.5 | 28.3 | 0 | 18.3 |
| Disked: Corn | 4 | ........ | ........ | ........ | ........ | 22.5 | 38.1 | 0 | 20.2 |
| Green manured: | | | | | | | | | |
| With rye | 3 | ........ | [b] 30.5 | [b] 11.2 | [b] 31.3 | [c] 23.6 | 49.5 | 0 | 24.4 |
| With peas | 2 | ........ | ........ | ........ | ........ | [d] 23.1 | 50.5 | 0 | 24.5 |
| Total or average | 5 | ........ | [b] 30.5 | [b] 11.2 | [b] 31.3 | [e] 23.5 | 49.9 | 0 | 24.4 |
| Summer tilled | 4 | [f] 22.0 | [f] 31.6 | [f] 17.5 | [f] 31.8 | 25.5 | 51.5 | 0 | 25.7 |
| Average of all 17 plats | ........ | 22.9 | 25.4 | 12.9 | 27.1 | 21.0 | 42.1 | 0 | 21.6 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Deep fall plowed (1 plat). | Shallow fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (4 plats). | Green manured (5 plats). | Summer tilled (4 plats). | Winter wheat (4 plats). | Corn (4 plats). |
| Yields of grain: | | | | | | | | | |
| 1910 bushels | 24.0 | 23.8 | 21.7 | 23.2 | ........ | ........ | [f] 22.0 | 23.2 | ........ |
| 1911 do | 23.5 | 22.0 | 22.3 | 22.4 | ........ | [b] 30.5 | [f] 31.6 | 22.6 | ........ |
| 1912 do | 12.2 | 13.2 | 10.8 | 12.5 | ........ | [b] 11.2 | [f] 17.5 | 12.2 | ........ |
| 1913 do | 23.2 | 25.5 | 24.3 | 26.2 | ........ | [b] 31.3 | [f] 31.8 | 24.8 | ........ |
| 1914 do | 16.3 | 16.3 | 20.1 | 15.5 | 22.5 | 23.5 | 25.5 | 17.1 | 22.5 |
| 1915 do | 28.5 | 25.0 | 21.1 | 28.3 | 38.1 | 49.7 | 51.5 | 25.7 | 38.1 |
| 1916 [a] do | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average | 18.2 | 18.0 | 17.2 | 18.3 | 20.2 | 24.4 | 25.7 | 17.9 | 20.2 |
| Crop value, cost, etc.: | | | | | | | | | |
| Value | $12.74 | $12.76 | $12.04 | $12.81 | $14.14 | $17.08 | $17.99 | ........ | ........ |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | ........ | ........ |
| Profit | 6.42 | 6.95 | 7.01 | 5.78 | 9.89 | 3.12 | 7.35 | ........ | ........ |

[a] The failure of winter wheat in 1916 was due to winterkilling.

[b] One plat, 1911 to 1913, inclusive.

[c] Two plats of rye in 1914.

[d] One plat of peas in 1914.

[e] Three plats in 1914.

[f] One plat, 1910 to 1914, inclusive.

The highest profit, $9.89 per acre, was obtained from disked corn ground. The value of this method as a farm practice will depend upon the profitable growth and utilization of the corn crop. Of the continuous-cropping methods, listing (on account of its inexpensiveness) has produced the next highest profit, which is $2.88 per acre less than the profit on disked corn ground.

Table V shows the profit from summer tillage to be next to that on disked corn ground. In the case of summer tillage and green manuring, however, the fact must be taken into account that a profit is secured only once in two years on the same ground. Green manuring, being even more expensive and less productive than summer tillage, has been the least profitable method. No difference is to be noted between peas and winter rye for green manure.

### HUNTLEY FIELD STATION.

The field station at Huntley, Mont., is located in the valley of the Yellowstone River, just below the first bench. The soil is a heavy gumbo to a depth of about 8 feet. Underlying the soil is a considerable depth of freely drained gravel. This soil carries a large supply of available water and allows deep feeding of the crop; consequently, it is possible to store in it a maximum quantity of water that can be recovered by the crop.

The Huntley station presents for study three years' results from some methods and four years' results from others.

As judged by average yields (Table VI), the methods practiced divide sharply into four groups, the production of the best method being more than double that of the poorest. These groups are summer tillage, with an average yield of 39.4 bushels; green manure, 30.6 bushels; disked corn ground, 25.8 bushels; and the various methods of preparing land continuously cropped to winter wheat, with averages ranging from 17.2 to 19 bushels per acre. The differences within this latter group are too small to be decisive, particularly as they are not consistent from year to year. As between peas and winter rye for green manure the advantage at this station is decidedly in favor of peas. In only one of the four years for which comparison is afforded has the yield following rye as green manure exceeded that following peas. The average yield after peas has been 5.2 bushels per acre greater than that after rye.

As judged by relative profits per acre, two methods—summer tillage, with an average profit of $16.94 per acre, and disked corn ground, with an average profit of $13.81 per acre—stand out as being distinctly superior to any of the other methods. The relatively high profit from summer tillage is due to the very high yield from that method, but the superiority of disked corn ground over the other methods, while due largely to high yields, may be attributed in part to the relatively low cost of the method. The profits of all other methods under trial range from $5.72 on deep fall plowing of winter wheat stubble to $7.92 on listed wheat stubble.

TABLE VI.—*Yields and cost of production of winter wheat by different methods at the Huntley Field Station, 1913 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | |
|---|---|---|---|---|---|---|
| | | 1913 | 1914 | 1915 | 1916 | Average. |
| Deep fall plowed: Winter wheat | 1 | ........ | 25.7 | 13.3 | 12.7 | 17.2 |
| Shallow fall plowed: Winter wheat | 1 | ........ | 30.8 | 12.3 | 13.7 | 18.9 |
| Listed: Winter wheat | 1 | ........ | 26.2 | 13.1 | 16.3 | 18.5 |
| Subsoiled: Winter wheat | 1 | ........ | 27.8 | 13.6 | 15.5 | 19.0 |
| Disked: Corn | 4 | 27.4 | 31.5 | 26.8 | 17.3 | 25.8 |
| Green manured: | | | | | | |
| With rye | 2 | 22.8 | 36.3 | 37.5 | 14.9 | 27.9 |
| With peas | 2 | 36.9 | 33.5 | 38.7 | 23.4 | 33.1 |
| Total or average | 4 | 29.9 | 34.9 | 38.2 | 19.2 | 30.6 |
| Summer tilled | 3 | 41.6 | 40.6 | [a] 56.1 | [b] 19.4 | 39.4 |
| Average of all 15 plats | ........ | 32.2 | 33.2 | [c] 38.0 | [d] 18.0 | 30.4 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Deep fall plowed (1 plat). | Shallow fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (4 plats). | Green manured (4 plats). | Summer tilled (3 plats). | Winter wheat (4 plats). | Corn (4 plats). |
| Yields of grain: | | | | | | | | | |
| 1913 bushels | ........ | ........ | ........ | ........ | 27.4 | 29.9 | 41.6 | ........ | 27.4 |
| 1914 do | 25.7 | 30.8 | 26.2 | 27.8 | 31.5 | 34.9 | 40.6 | 27.6 | 31.5 |
| 1915 do | 13.3 | 12.3 | 13.1 | 13.6 | 26.8 | 38.2 | [a] 56.1 | 13.1 | 26.8 |
| 1916 do | 12.7 | 13.7 | 16.3 | 15.5 | 17.3 | 19.2 | [b] 19.4 | 14.6 | 17.3 |
| Average | 17.2 | 18.9 | 18.5 | 19.0 | 25.8 | 30.6 | 39.4 | 18.4 | 25.8 |
| Crop value cost, etc.: | | | | | | | | | |
| Value | $12.04 | $13.23 | $12.95 | $13.30 | $18.06 | $21.42 | $27.58 | ........ | ........ |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | ........ | ........ |
| Profit | 5.72 | 7.58 | 7.92 | 6.27 | 13.81 | 7.46 | 16.94 | ........ | ........ |

[a] Eight plats in 1915. [b] Nine plats in 1916. [c] Twenty plats in 1915. [d] Twenty-one plats in 1916.

## BELLE FOURCHE FIELD STATION.

The field station near Newell, S. Dak., on the Belle Fourche Reclamation Project, is located on a heavy gumbo clay soil. The soil is derived from the decomposition of Pierre shale. From the soil at the surface there is a rapid change to broken but undecomposed shale. Near the bottom of the second foot is a comparatively impervious layer of soil. The first foot and at least a part of the second foot carry a large supply of available water. It is probable that but little use is made of either water or soil below the first 2 feet. In spite of the heavy soil and the large supply of water that can be obtained by the plant from that portion of it near the surface, the shallowness of feeding reduces the quantity of available water that can be carried in the soil to about one-half of that available in deeper soils. The result of this is shown in the yields. (Table VII.)

TABLE VII.—*Yields and cost of production of winter wheat by different methods at the Belle Fourche Field Station, 1909 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 34.4 | 0 | 0 | 0 | 21.8 | 13.4 | 20.4 | 8.8 | 12.4 |
| Late fall plowed: Winter wheat | 1 | 19.0 | 0 | 0 | 0 | 16.2 | 15.1 | 34.8 | 16.1 | 12.7 |
| Listed: Winter wheat | 1 | 29.3 | 0 | 0 | 0 | 13.4 | 15.2 | 41.2 | 15.2 | 14.3 |
| Subsoiled: Winter wheat | 1 | 29.3 | 0 | 0 | 0 | 18.7 | 14.7 | 25.2 | 8.5 | 12.1 |
| Summer tilled | 1 | 32.4 | 9.2 | 0 | 0 | 36.5 | 32.5 | 59.3 | 14.8 | 23.1 |
| Average of all 5 plats | ...... | 28.9 | 1.8 | ...... | ...... | 21.3 | 18.2 | 36.2 | 12.7 | 14.9 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | Previous crop. |
|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Summer tilled (1 plat). | Winter wheat (4 plats). |
| Yields of grain: | | | | | | |
| 1909 bushels | 34.4 | 19.0 | 29.3 | 29.3 | 32.4 | 28.0 |
| 1910 do | 0 | 0 | 0 | 0 | 9.2 | 0 |
| 1911 do | 0 | 0 | 0 | 0 | 0 | 0 |
| 1912 do | 0 | 0 | 0 | 0 | 0 | 0 |
| 1913 do | 21.8 | 16.2 | 13.4 | 18.7 | 36.5 | 17.5 |
| 1914 do | 13.4 | 15.1 | 15.2 | 14.7 | 32.5 | 14.6 |
| 1915 do | 20.4 | 34.8 | 41.2 | 25.2 | 59.3 | 30.4 |
| 1916 do | 8.8 | 16.1 | 15.2 | 8.5 | 14.8 | 12.2 |
| Average | 12.4 | 12.7 | 14.3 | 12.1 | 23.1 | 12.8 |
| Crop value, cost, etc.: | | | | | | |
| Value | $8.68 | $8.89 | $10.01 | $8.47 | $16.17 | ......... |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 10.64 | ......... |
| Profit | 2.36 | 3.24 | 4.98 | 1.44 | 5.53 | ......... |

During the last eight years there have been two total failures of winter wheat (1911 and 1912) at the Belle Fourche station. In 1910 the only wheat produced was 9.2 bushels per acre on summer-tilled land. The average yield from summer tillage is almost double that from any other method, though in 1909 the yield from this method was less than from early fall plowing. Listing has produced the highest average yield of the continuous-cropping methods. While the average result shows a difference of only 0.3 of a bushel between early and late fall plowing, wide differences have been exhibited in the individual years. Generally the early fall plowing is very lumpy and is difficult to work down to form a compact seed bed. In years when there is considerable fall precipitation it is possible to work the early fall plowing into excellent condition for seeding. When this condition occurs, little difference is shown between early and late fall plowing. In years when the fall precipitation is limited, both the best stand and the best winter survival are found on late fall plowing. This condition is shown particularly in the results of 1915 and 1916. The wide margin of difference in favor of early fall plowing in 1909 is due to the fact that at that time the grass still persisted on the late fall-plowed land. No winter wheat has been sown on disked corn ground at this station.

Summer tillage shows the highest profit, $5.53 per acre. Listing is the most profitable of the continuous-cropping methods. Subsoiling, on account of the expense involved, is the least profitable of the methods studied. Late fall plowing has given appreciably larger net returns than early fall plowing, as the extra labor involved in the latter method on the average does not increase the yield.

### ARDMORE FIELD STATION.

Two types of soil are found on the Ardmore farm—Orman clay and Pierre clay. Both of these types hold a high percentage of available water and should show favorable results from the cultural methods that store moisture. In the Orman clay, on which type of soil most of the experiments have been conducted, gravel is found at depths of 2 to 4 feet. Crop yields have not been limited so much by the inability of the soil to hold all of the moisture taken in as by the texture of the soil, which makes penetration of rain on fallow land difficult.

At Ardmore winter wheat failed in 1913 under all methods except summer tillage, which averaged in that year 8 bushels per acre. In 1914 the crop was destroyed by hail. In the other two years under study the yields were good under all methods. Summer tillage has produced the highest average yield, but in 1916 three of the other methods gave higher yields. Early fall plowing, late fall plowing, and listing have averaged approximately the same. The difference in yield between subsoiling and disked corn ground is very small, both averaging considerably higher than early or late fall plowing or listing. (Table VIII.)

The profits from summer tillage and green manuring are decidedly less than from the continuous cropping methods. The highest net return, $11.29 per acre, has been obtained from disked corn ground. Late fall plowing, involving less expense, has been more profitable than early fall plowing. While subsoiling has produced higher yields than listing, the profits from the two methods are approximately equal. On land continuously cropped to winter wheat, higher profits have been secured from subsoiling and listing than from early or late fall plowing.

TABLE VIII.—*Yields and cost of production of winter wheat by different methods at the Ardmore Field Station, 1913 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | |
|---|---|---|---|---|---|---|
| | | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 0 | (a) | 29.2 | 29.8 | 19.7 |
| Late fall plowed: Winter wheat | 1 | 0 | (a) | 30.0 | 27.0 | 19.0 |
| Listed: Winter wheat | 1 | 0 | (a) | 25.0 | 34.0 | 19.7 |
| Subsoiled: Winter wheat | 1 | 0 | (a) | 33.3 | 34.5 | 22.6 |
| Disked: Corn | 3 | 0 | (a) | 36.4 | 30.1 | 22.2 |
| Green manured: | | | | | | |
| With rye | 1 | 0 | (a) | 30.2 | 33.5 | 21.2 |
| With peas | 1 | 0 | (a) | 30.8 | 31.3 | 20.7 |
| Total or average | 2 | 0 | .......... | 30.5 | 32.4 | 21.0 |
| Summer tilled | 3 | [b] 8.0 | (a) | 37.0 | 31.6 | 25.5 |
| Average of all 12 plats | .......... | [c] 1.4 | .......... | 33.2 | 31.3 | 22.0 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (3 plats). | Green manured (2 plats). | Summer tilled (3 plats). | Winter wheat (4 plats). | Corn (3 plats). |
| Yields of grain: | | | | | | | | | |
| 1913.............bushels.. | 0 | 0 | 0 | 0 | 0 | 0 | [b] 8.0 | 0 | 0 |
| 1914.............do.... | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) | (a) |
| 1915.............do.... | 29.2 | 30.0 | 25.0 | 33.3 | 36.4 | 30.5 | 37.0 | 29.4 | 36.4 |
| 1916.............do.... | 29.8 | 27.0 | 34.0 | 34.5 | 30.1 | 32.4 | 31.6 | 31.3 | 30.1 |
| Average | 19.7 | 19.0 | 19.7 | 22.6 | 22.2 | 21.0 | 25.5 | 20.2 | 22.2 |
| Crop value, cost, etc.: | | | | | | | | | |
| Value | $13.79 | $13.30 | $13.79 | $15.82 | $15.54 | $14.70 | $17.85 | ........ | ........ |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | ........ | ........ |
| Profit | 7.47 | 7.65 | 8.76 | 8.79 | 11.29 | .74 | 7.21 | ........ | ........ |

[a] Destroyed by hail. [b] Two plats in 1913. [c] Eleven plats in 1913.

## SCOTTSBLUFF FIELD STATION.

The work at Scottsbluff, Nebr., is conducted at a field station located on the North Platte Irrigation Project. The soil is a comparatively light sandy loam. At a depth varying from 5 to 8 feet there is a sharp break from sandy loam to either sand or Brule clay. Above this point the soil offers no unusual resistance to the downward passage of water or to the development of roots. Owing to its light character, however, it is possible to store in it only a moderate supply of available water. In respect to this point it is somewhere intermediate between the Belle Fourche and the North Platte soils.

At the Scottsbluff station summer tillage has produced the highest average yield, though higher yields were produced in 1913 by early fall plowing, disked corn ground, and rye as green manure; in 1914 by disked corn ground and rye as green manure, and in 1916 by rye and peas as green manure and by disked corn ground. The average yield of 15.4 bushels per acre from disked corn ground is higher than that following any other harvested crop, but is 5.2 bushels less than on summer tillage and 0.7 bushel less than on rye as green manure. The yields after rye as a green-manure crop have been consistently higher than the yields after peas. Ground plowed early in the fall yields nearly twice as much on the average as ground plowed late, but only about three-fifths as much as disked corn ground. The results from listing and subsoiling are not sufficient for comparison with the results obtained from other methods. (Table IX.)

TABLE IX.—*Yields and cost of production of winter wheat by different methods at the Scottsbluff Field Station, 1912 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1912 | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 6.3 | 7.7 | 17.8 | 8.7 | 5.2 | 9.1 |
| Late fall plowed: Winter wheat | 1 | 0 | 0 | 12.8 | 11.7 | 2.5 | 5.4 |
| Listed: Winter wheat | 1 | | | | | 3.8 | 3.8 |
| Subsoiled: Winter wheat | 1 | | | 22.3 | | 5.0 | 13.7 |
| Disked: Corn | 3 | 15.6 | 10.5 | 18.2 | 25.7 | 6.9 | 15.4 |
| Green manured: | | | | | | | |
| With rye | 1 | 14.0 | 9.0 | 26.7 | 23.8 | 7.0 | 16.1 |
| With peas | 1 | 12.3 | 6.3 | 23.3 | | 6.3 | 12.1 |
| Total or average | 2 | 13.2 | 7.7 | 25.0 | [a] 23.8 | 6.7 | 15.3 |
| Summer tilled | 2 | 20.9 | 6.8 | 32.0 | 37.0 | 6.2 | 20.6 |
| Average of all 11 plats | | 13.5 | 7.5 | 22.1 | 22.2 | 5.7 | 14.2 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (3 plats). | Green manured (2 plats). | Summer tilled (2 plats). | Winter wheat (4 plats). | Corn (3 plats). |
| Yields of grain: | | | | | | | | | |
| 1912 bushels | 6.3 | 0 | | | 15.6 | 13.2 | 20.9 | [b] 3.2 | 15.6 |
| 1913 do | 7.7 | 0 | | | 10.5 | 7.7 | 6.8 | [b] 3.9 | 10.5 |
| 1914 do | 17.8 | 12.8 | | 22.3 | 18.2 | 25.0 | 32.0 | [c] 17.6 | 18.2 |
| 1915 do | 8.7 | 11.7 | | | 25.7 | [a] 23.8 | 37.0 | 4.1 | 25.7 |
| 1916 do | 5.2 | 2.5 | 3.8 | 5.0 | 6.9 | 6.7 | 6.2 | 8.0 | 6.9 |
| Average | 9.1 | 5.4 | 3.8 | 13.7 | 15.4 | 15.3 | 20.6 | 7.4 | 15.4 |
| Crop value, cost, etc.: | | | | | | | | | |
| Value | $6.37 | $3.78 | $2.66 | $9.59 | $10.78 | $10.71 | $14.42 | | |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | | |
| Profit or loss | .05 | −1.87 | −2.37 | 2.56 | 6.53 | −3.25 | 3.78 | | |

[a] One plat in 1915. [b] Two plats in 1912 and 1913. [c] Three plats in 1914.

Disked corn ground has averaged the largest profit—$6.53 per acre. The next highest profit has been secured from summer tillage. Excepting subsoiling, since only two years' results are available for this method, the only other method showing a profit is early fall plowing, with a nominal one of $0.05 per acre. Green manuring and late fall plowing show losses of $3.25 and $1.87 per acre, respectively. The loss shown for listing is for one year, 1916, when none of the methods except disked corn ground produced a profit.

### NORTH PLATTE FIELD STATION.

The work here presented is conducted on the table-land of the North Platte Field Station. The soil is of the type generally known as loess. With the exception of the humus accumulated near the surface, it is practically uniform to great depths. The storage and use of water is unlimited by the depth of the soil or any peculiarities in it. The development of roots is limited only by the physiological character of the crops grown and the available moisture. It is a soil on which a maximum of results from tillage methods would be expected.

The highest average yield of winter wheat at the North Platte station has been 22.6 bushels per acre, obtained after rye as a green-manure crop, a yield of 0.5 bushel higher than that on disked corn ground, which shows the next highest average. The yields after peas have averaged 2.3 bushels less than the yields after rye. The yields on disked ground after potatoes, winter wheat, and oats have averaged 3.7, 7.5, and 9 bushels less, respectively, than on disked corn ground. The yields from summer tillage have averaged higher than from any of the continuous cropping methods except disked corn ground. Early fall plowing has given higher yields than late fall plowing, and late fall plowing of winter-wheat stubble has given higher yield than disking winter-wheat stubble. Disked oat ground has given the lowest average yield. The most profitable method has been disked corn ground, with disked potato ground next. Disking as compared with summer tillage, green manuring, or plowing following the same crop has been the more profitable method except where the crop followed oats. Plowing oat stubble has given a sufficiently higher yield than disking the same to make it the more profitable method. On land continuously cropped to winter wheat the average profit from early fall plowing has been the same as from late fall plowing. The profit from summer tillage has been much greater than from green manuring, but less than from any method producing a crop each year. (Table X.)

Winter wheat was grown in field tests at the station during the years 1907 to 1911, inclusive, on land summer tilled the year preceding the wheat crop and on land continuously cropped to winter wheat and early fall plowed. The figures have been published in Nebraska Bulletins Nos. 118 and 135 and in United States Department of Agriculture Bulletin No. 268, entitled "Crop Production in the Great Plains Area." These figures, averaged with the results obtained on the dry-land agriculture rotations from summer tillage and early fall plowing of winter-wheat stubble for the years 1912 to 1916, inclusive, show an average yield for the 10 years of 30.6 bushels per acre from summer tillage and 15.3 bushels on early fall plowing.

TABLE X.—*Yields and cost of production of winter wheat by different methods at the North Platte Field Station, 1912 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1912 | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: | | | | | | | |
| Winter wheat | 1 | 7.7 | 3.8 | 4.7 | 39.8 | 28.3 | 16.9 |
| Winter wheat (manured) | 1 | 9.3 | 2.2 | 4.5 | 31.2 | 31.3 | 15.7 |
| Oats | 1 | 10.5 | 3.8 | 7.2 | 42.5 | 23.0 | 17.4 |
| Total or average | 3 | 9.2 | 3.3 | 5.5 | 37.8 | 27.5 | 16.7 |
| Late fall plowed: Winter wheat | 1 | 7.2 | 3.2 | 3.3 | 39.7 | 23.5 | 15.4 |
| Disked: | | | | | | | |
| Winter wheat | 2 | 1.5 | 4.3 | 3.0 | 38.0 | 26.3 | 14.6 |
| Corn | 9 | 10.0 | 16.9 | 8.0 | 37.3 | 38.4 | 22.1 |
| Oats | 2 | 0 | 7.1 | 3.3 | 42.6 | 12.4 | 13.1 |
| Potatoes | 1 | 0 | 14.5 | 7.5 | 36.3 | 33.6 | 18.4 |
| Total or average | 14 | 6.6 | 13.5 | 6.6 | 38.0 | 32.6 | 19.5 |
| Green manured: | | | | | | | |
| With rye | 1 | 28.2 | 24.0 | 8.3 | 18.3 | 34.3 | 22.6 |
| With peas | 1 | 23.8 | 15.5 | 11.7 | 25.3 | 25.3 | 20.3 |
| Total or average | 2 | 26.0 | 19.8 | 10.0 | 21.8 | 29.8 | 21.5 |
| Summer tilled | 5 | 12.7 | 23.7 | 10.1 | 31.7 | 30.0 | 21.6 |
| Average of all 25 plats | ........ | 9.7 | 14.4 | 7.3 | 35.5 | 30.9 | 19.6 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yield, values, etc. (average per acre). | Tillage treatment. | | | | | Previous crop. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (3 plats). | Late fall plowed (1 plat). | Disked (14 plats). | Green manured (2 plats). | Summer tilled (5 plats). | All small grain (8 plats). | Winter wheat (5 plats). | Oats (3 plats). | Corn (9 plats). | Potatoes (1 plat). |
| Yields of grain: | | | | | | | | | | |
| 1912......bushels.. | 9.2 | 7.2 | 6.6 | 26.0 | 12.7 | 4.7 | 5.4 | 3.5 | 10.0 | 0 |
| 1913..........do.... | 3.3 | 3.2 | 13.5 | 19.8 | 23.7 | 4.5 | 3.5 | 6.0 | 16.9 | 14.5 |
| 1914..........do.... | 5.5 | 3.3 | 6.6 | 10.0 | 10.1 | 4.0 | 3.7 | 4.6 | 8.0 | 7.5 |
| 1915..........do.... | 37.8 | 39.7 | 38.0 | 21.8 | 31.7 | 39.3 | 37.3 | 42.5 | 37.3 | 36.3 |
| 1916..........do.... | 27.5 | 23.5 | 32.6 | 29.8 | 30.0 | 22.9 | 27.1 | 15.9 | 38.4 | 33.6 |
| Average | 16.7 | 15.4 | 19.5 | 21.5 | 21.6 | 15.1 | 15.4 | 14.5 | 22.1 | 18.4 |
| Crop value, cost, etc.: | | | | | | | | | | |
| Value | $11.69 | $10.78 | $13.65 | $15.05 | $15.12 | ........ | ........ | ........ | ........ | ........ |
| Cost | 6.32 | 5.65 | 4.25 | 13.96 | 10.64 | ........ | ........ | ........ | ........ | ........ |
| Profit | 5.37 | 5.13 | 9.40 | 1.09 | 4.48 | ........ | ........ | ........ | ........ | ........ |

### ARCHER FIELD STATION.

The work at the Archer station is on a very high upland. The soil is a uniform, medium-dark sandy loam, with some fine gravel distributed very evenly through it. At a depth of 3 to 6 feet the soil is underlain with a bed of gravel. Commonly a hardpan of particles of fine sand cemented together is found overlying this bed of gravel. Water does not leach readily through this compact layer.

The results from the Archer station are so meager that no definite conclusions can be drawn. In 1914 there was a total failure due to winterkilling under all methods, while in 1916 the stands on the disked corn ground and green-manure plats were destroyed by drifting soil from an adjacent field. Summer tillage has produced higher average yields than the continuous cropping methods for which three years' results are available. The average yields from early fall plowing and late fall plowing are approximately equal and are slightly higher than the yields from listing and subsoiling. (Table XI.)

TABLE XI.—*Yields and cost of production of winter wheat by different methods at the Archer Field Station, 1914 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | |
|---|---|---|---|---|---|
| | | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 0 | 24.7 | 7.4 | 10.7 |
| Late fall plowed: Winter wheat | 1 | 0 | 25.9 | 4.2 | 10.0 |
| Listed: Winter wheat | 1 | 0 | 21.2 | 5.4 | 8.9 |
| Subsoiled: Winter wheat | 1 | 0 | 24.2 | 2.4 | 8.9 |
| Disked: Corn | 3 | 0 | 27.1 | (a) | 13.6 |
| Green manured: | | | | | |
| With rye | 1 | 0 | 25.3 | (a) | 12.7 |
| With peas | 1 | 0 | 29.7 | (a) | 14.9 |
| Total or average | 2 | | 27.5 | | 13.8 |
| Summer tilled | 3 | (b) | 26.4 | [c] 11.4 | 12.6 |
| Average of all 12 plats | | | 26.0 | [d] 6.2 | 10.7 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (3 plats). | Green manured (2 plats). | Summer tilled (3 plats). | Winter wheat (4 plats). | Corn (3 plats). |
| Yields of grain: | | | | | | | | | |
| 1914 bushels | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1915 do | 24.7 | 25.9 | 21.2 | 24.2 | 27.1 | 27.5 | 26.4 | 24.0 | 27.1 |
| 1916 do | 7.4 | 4.2 | 5.4 | 2.4 | (a) | (a) | [c] 11.4 | 4.9 | (a) |
| Average | 10.7 | 10.0 | 8.9 | 8.9 | 13.6 | 13.8 | 12.6 | 9.6 | 13.6 |
| Crop value, cost, etc.: | | | | | | | | | |
| Value | $7.49 | $7.00 | $6.23 | $6.23 | $9.52 | $9.66 | $8.82 | | |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | | |
| Profit or loss | 1.17 | 1.35 | 1.20 | −0.80 | 5.27 | −4.30 | −1.82 | | |

[a] Stands destroyed by drifting soil in 1916.
[b] Two plats in 1914.
[c] One plat in 1916; stands on the others destroyed by drifting soil.
[d] Five plats in 1916.

Late fall plowing has been slightly more profitable than either early fall plowing or listing. Green manuring, summer tillage, and subsoiling have not proved profitable, green manuring showing the greatest loss. As an average for the two years for which results are available from disked corn ground, this method has given much higher net returns than any other method.

### AKRON FIELD STATION.

The soil of the field station at Akron, Colo., is of a clay-loam type locally known as "tight land." It is characterized in the native vegetation by a growth of short grass. As it carries in each unit section a considerable supply of water and as it offers no physical obstruction to the development of roots, it is possible to store in it a large quantity of water available to a crop. It is a soil on which maximum results would be expected from methods of tillage calculated to store water. (Table XII.)

TABLE XII.—*Yields and cost of production of winter wheat by different methods at the Akron Field Station, 1910 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 10.3 | 6.8 | 26.7 | 2.0 | 24.8 | 20.8 | 4.2 | 13.7 |
| Late fall plowed: Winter wheat | 1 | 11.4 | 1.7 | 25.8 | 3.3 | 24.5 | 22.0 | 4.2 | 13.3 |
| Listed: Winter wheat | 1 | 8.8 | 6.0 | 30.0 | 7.2 | 21.3 | 18.2 | 7.7 | 14.2 |
| Subsoiled: Winter wheat | 1 | 6.9 | 3.3 | 21.2 | 3.2 | 24.5 | 21.0 | 3.8 | 12.0 |
| Disked: Corn | 3 | 17.7 | 3.1 | 36.3 | 11.4 | 27.7 | 26.2 | 15.3 | 19.7 |
| Green manured: | | | | | | | | | |
| With rye | 4 | 15.7 | 3.8 | 36.8 | 8.4 | 26.4 | 25.7 | 19.2 | 19.4 |
| With peas | 4 | 12.7 | 2.4 | 33.2 | 4.2 | 23.1 | 13.8 | 9.7 | 14.2 |
| Total or average | 8 | 14.2 | 3.1 | 35.0 | 6.3 | 24.7 | 19.7 | 14.5 | 16.8 |
| Summer tilled | 2 | 18.0 | 10.5 | 40.9 | 12.7 | 27.0 | 27.4 | 24.9 | 23.1 |
| Average of all 17 plats | ........ | 14.1 | 4.3 | 33.8 | 7.4 | 25.3 | 22.0 | 13.6 | 17.2 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (3 plats). | Green manured (8 plats). | Summer tilled (2 plats). | Winter wheat (4 plats). | Corn (3 plats). |
| Yields of grain: | | | | | | | | | |
| 1910 bushels | 10.3 | 11.4 | 8.8 | 6.9 | 17.7 | 14.2 | 18.0 | 9.4 | 17.7 |
| 1911 do | 6.8 | 1.7 | 6.0 | 3.3 | 3.1 | 3.1 | 10.5 | 4.5 | 3.1 |
| 1912 do | 26.7 | 25.8 | 30.0 | 21.2 | 36.3 | 35.0 | 40.9 | 25.9 | 36.3 |
| 1913 do | 2.0 | 3.3 | 7.2 | 3.2 | 11.4 | 6.3 | 12.7 | 3.9 | 11.4 |
| 1914 do | 24.8 | 24.5 | 21.3 | 24.5 | 27.7 | 24.7 | 27.0 | 23.8 | 27.7 |
| 1915 do | 20.8 | 22.0 | 18.2 | 21.0 | 26.2 | 19.7 | 27.4 | 20.5 | 26.2 |
| 1916 do | 4.2 | 4.2 | 7.7 | 3.8 | 15.3 | 14.5 | 24.9 | 5.0 | 15.3 |
| Average | 13.7 | 13.3 | 14.2 | 12.0 | 19.7 | 16.8 | 23.1 | 13.3 | 19.7 |
| Crop value, cost, etc.: | | | | | | | | | |
| Value | $9.59 | $9.31 | $9.94 | $8.40 | $13.79 | $11.76 | $16.17 | ........ | ........ |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | ........ | ........ |
| Profit or loss | 3.27 | 3.66 | 4.91 | 1.37 | 9.54 | −2.20 | 5.53 | ........ | ........ |

At the Akron station the highest average yield, 23.1 bushels per acre, has been obtained from summer tillage. The yields from summer tillage have been higher than from any other method each year except in 1914, when the yield on disked corn ground was 0.7 bushel higher. Disked corn ground, with an average of 19.7 bushels, has given the next highest yield. The average after rye as a green-manure crop is 0.3 bushel less than that on disked corn ground, while the average after peas is 5.5 bushels less. The yield after peas every year has been lower than after rye. The yield after peas is no greater than from some of the continuous-cropping methods. There is very little difference in the average yields from early fall plowing, late fall plowing, and listing. Subsoiling has given the lowest average yield.

Disked corn ground has given the highest net returns, $9.54 per acre, almost double the profit from listing, the next most profitable of the continuous-cropping methods. The profit from disked corn ground exceeds that from summer tillage by $4.01. Late fall plowing, while averaging slightly less in yield, has given somewhat higher net returns than early fall plowing, because it is a cheaper method. Subsoiling has been the least profitable of the continuous-cropping methods. The only loss sustained is $2.20 per acre from green manuring. This loss is due entirely to the peas, which show a loss of $5.65, whereas rye has averaged a profit of $1.12 per acre.

### HAYS FIELD STATION.

The soil on which the experimental work has been conducted at the station at Hays, Kans., is a heavy silt loam. It can carry a large quantity of water available to a crop. Penetration to the lower depths, however, is slow. The very compact zone in the third foot offers marked resistance both to the downward passage of water and to the development of roots. While the evidence is not as complete as might be desired, it appears that the proportion of water that can be stored in this soil is somewhat above the average.

Summer tillage has produced the highest average yield, 22.7 bushels, of winter wheat at the Hays station, though in 1907, 1914, and 1915 the yields from some of the other methods have exceeded those from summer tillage. The next highest average yields, 19.6 and 19.2 bushels, were obtained from subsoiling and listing, respectively. The average yield of 17.6 bushels from early fall plowing is 6.6 bushels greater than that from late fall plowing, the yields from the former method being larger than from the latter method every year except in 1908. Disked corn ground has averaged 2.2 bushels less than early fall plowing and 4.4 bushels more than late fall plowing. The yields from green manuring average 5.7 bushels less than for summer tillage and are lower than from any of the other methods except late fall plowing and disked corn ground. The yields after rye and after peas average practically the same, though in 1908 the yield after peas was very much lower and in 1910 very much higher than the yield after rye. Previous to 1910 cowpeas were used instead of common field peas. (Table XIII.)

TABLE XIII.—*Yields and cost of production of winter wheat by different methods at the Hays Field Station, 1907 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1907 | 1908 | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 18.2 | 23.2 | [a] H | 27.8 | 0.3 | 13.8 | 2.3 | 24.8 | [b]18.1 | [b]29.7 | 17.6 |
| Late fall plowed: Winter wheat | 1 | 11.7 | 25.6 | H | 20.3 | 0 | 2.3 | .8 | 20.6 | 9.3 | 8.7 | 11.0 |
| Listed: Winter wheat | 1 | 12.4 | 28.1 | H | 36.7 | .6 | 26.6 | 8.4 | 23.1 | 13.9 | 23.1 | 19.2 |
| Subsoiled: Winter wheat | 1 | 13.6 | 30.5 | H | 39.8 | .3 | 20.1 | 4.1 | 25.3 | 14.9 | 27.6 | 19.6 |
| Disked: Corn | 4 | 8.2 | 11.1 | H | 28.2 | .3 | 13.6 | 7.2 | 18.0 | 20.1 | 31.7 | 15.4 |
| Green manured: | | | | | | | | | | | | |
| With rye | 2 | 10.9 | 22.5 | H | 26.8 | 1.8 | 6.6 | 8.4 | 21.7 | 20.8 | 31.3 | 16.8 |
| With peas [c] | 2 | 14.3 | [d]9.4 | H | 39.7 | 2.0 | 7.5 | 5.7 | 23.0 | 20.9 | 31.5 | 17.1 |
| Total or average | 4 | 12.6 | [e]18.1 | ...... | 33.2 | 1.9 | 7.0 | 7.1 | 21.1 | 20.8 | 31.4 | 17.0 |
| Summer tilled | 2 | [d]12.3 | 30.7 | H | 42.6 | 3.9 | 28.5 | 13.4 | 20.8 | [f]16.4 | [f]36.0 | 22.7 |
| Average of all 14 plats | ........ | 11.6 | 20.6 | ...... | 32.5 | 1.3 | 14.4 | 7.1 | 20.8 | [g]17.0 | [g]33.7 | 17.7 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (4 plats). | Green manured (4 plats). | Summer tilled (2 plats). | Winter wheat (4 plats). | Corn (4 plats). |
| Yields of grain: | | | | | | | | | |
| 1907 bushels | 18.2 | 11.7 | 12.4 | 13.6 | 8.2 | 12.6 | [d] 12.3 | 14.0 | 8.2 |
| 1908 do | 23.2 | 25.6 | 28.1 | 30.5 | 11.1 | [e] 18.1 | 30.7 | 26.9 | 11.1 |
| 1909 do | [a] H | H | H | H | H | H | H | H | H |
| 1910 do | 27.8 | 20.3 | 36.7 | 39.8 | 28.2 | 33.2 | 42.6 | 31.2 | 28.2 |
| 1911 do | .3 | 0 | .6 | .3 | .3 | 1.9 | 3.9 | .3 | .3 |
| 1912 do | 13.8 | 2.3 | 26.6 | 20.1 | 13.6 | 7.0 | 28.5 | 15.7 | 13.6 |
| 1913 do | 2.3 | .8 | 8.4 | 4.1 | 7.2 | 7.1 | 13.4 | 3.9 | 7.2 |
| 1914 do | 24.8 | 20.6 | 23.1 | 25.3 | 18.0 | 21.1 | 20.8 | 23.5 | 18.0 |
| 1915 do | [b] 18.1 | 9.3 | 13.9 | 14.9 | 20.1 | 20.8 | [f] 16.4 | [h] 15.4 | 20.1 |
| 1916 do | [b] 29.7 | 8.7 | 23.1 | 27.6 | 31.7 | 31.4 | [f] 36.0 | [h] 24.8 | 31.7 |
| Average | 17.6 | 11.0 | 19.2 | 19.6 | 15.4 | 17.0 | 22.7 | 18.4 | 15.4 |
| Crop value, cost, etc.: | | | | | | | | | |
| Value | $12.32 | $7.70 | $13.44 | $13.72 | $10.78 | $11.90 | $15.89 | ........ | ........ |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | ........ | ........ |
| Profit or loss | 6.00 | 2.05 | 8.41 | 6.69 | 6.53 | −2.06 | 5.25 | ........ | ........ |

[a] H=destroyed by hail.
[b] Three plats in 1915 and 1916.
[c] Cowpeas were grown from 1906 to 1909; field peas grown since 1909.
[d] One plat.
[e] Three plats in 1908.
[f] Thirty-one plats.
[g] Forty-five plats in 1915 and 1916.
[h] Six plats in 1915 and 1916.

The highest profit has been obtained from listing, which yields a greater profit than subsoiling, because it is a less expensive method. The profit on disked corn ground is slightly lower than from subsoiling and somewhat larger than from early fall plowing. The practicability of the method of using disked corn ground depends on the value of the corn crop. Late fall plowing, on account of the poor yields obtained from this method, shows the lowest profit, while summer tillage, on account of the cost of the method, has given next to the lowest profit. The yields from green manuring have not been sufficient to pay the cost of production by this method.

### GARDEN CITY FIELD STATION.

The work at Garden City, Kans., is on a high upland. The soil is a light silt loam. With the exception of the accumulated humus near the surface, it is practically uniform to a depth of at least 15 feet. The development of roots is limited only by the depth to which water is available and by the physiological character of the crop. The light character of the soil, however, makes it possible to store in each unit of it only a comparatively small quantity of water. This is not entirely overcome by the depth of the soil. The results in storing water have been determined largely by the limited quantity available for storage. In no year under any method practiced has the soil been filled with water to as great a depth as it is possible for the crop to develop roots and use available water. (Table XIV.)

TABLE XIV.—*Yield and cost of production of winter wheat by different methods at the Garden City Field Station, 1909 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1909 | 1910 | 1911 | 1912 | [a] 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 0 | 0 | 0 | 0 | ....... | 6.3 | 10.0 | 0 | 2.3 |
| Late fall plowed: Winter wheat | 1 | 0 | 0 | 0 | 0 | ....... | 7.3 | 10.0 | 0 | 2.5 |
| Listed: Winter wheat | 3 | 0 | 0 | 0 | 0 | ....... | 8.9 | 12.6 | 2.1 | 3.4 |
| Subsoiled: Winter wheat | 1 | 0 | 0 | 0 | 0 | ....... | 16.7 | 9.9 | 0 | 3.8 |
| Disked: | | | | | | | | | | |
| Corn | [b] 1 | 0 | 0 | 0 | 0 | ....... | 8.7 | 16.8 | 0 | 3.6 |
| Potatoes | 1 | ....... | ....... | ....... | ....... | ....... | 7.3 | 12.8 | 1.2 | 7.1 |
| Total or average | 2 | 0 | 0 | 0 | 0 | ....... | 8.0 | 14.8 | .6 | 3.3 |
| Green manured: | | | | | | | | | | |
| With rye | [c] 2 | 0 | 0 | 0 | 0 | ....... | 16.1 | 9.0 | 10.0 | 5.0 |
| With peas | [d] 1 | 0 | 0 | 0 | 0 | ....... | 14.5 | 16.8 | 7.2 | 5.5 |
| Total or average | [e] 3 | 0 | 0 | 0 | 0 | ....... | 15.5 | 11.6 | 9.1 | 5.2 |
| Summer tilled | [f] 11 | 0 | 0 | 0 | 0 | ....... | 12.5 | 21.3 | 7.7 | 5.9 |
| Average of all 22 [g] plats | ....... | 0 | 0 | 0 | 0 | ....... | 11.4 | 16.7 | 5.4 | 4.8 |

[a] Birds destroyed the young wheat plants in the fall, and the plats were reseeded to spring wheat.

[b] Two plats, 1909 to 1913, inclusive.

[c] Five plats, 1909 to 1913, inclusive.

[d] Four plats, 1909 to 1913, inclusive.

[e] Nine plats, 1909 to 1913, inclusive.

[f] Two plats, 1909 to 1912, inclusive.

[g] Sixteen plats, 1909 to 1912, inclusive; 29 in 1913.

TABLE XIV.—*Yield and cost of production of winter wheat by different methods at the Garden City Field Station, 1909 to 1916, inclusive*—Continued.

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (3 plats). | Subsoiled (1 plat). | Disked (2 plats). | Green manured (3 plats).[a] | Summer tilled (11 plats).[b] | Winter wheat (6 plats). | Corn (1 plat).[c] | Potatoes (1 plat). |
| Yields of grain: | | | | | | | | | | |
| 1909....bushels.. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ....... |
| 1910.......do.... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ....... |
| 1911.......do.... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ....... |
| 1912.......do.... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ....... |
| 1913 [d].....do.... | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ....... |
| 1914.......do.... | 6.3 | 7.3 | 8.9 | 16.7 | 8.0 | 15.5 | 12.5 | 12.8 | 8.7 | 7.3 |
| 1915.......do.... | 10.0 | 10.0 | 12.6 | 9.9 | 14.8 | 11.6 | 21.3 | 11.3 | 16.8 | 12.8 |
| 1916.......do.... | 0 | 0 | 2.1 | 0 | .6 | 9.1 | 7.4 | 1.1 | 0 | 1.2 |
| Average........ | 2.3 | 2.5 | 3.4 | 3.8 | 3.3 | 5.2 | 5.9 | 3.6 | 3.6 | 7.1 |
| Crop value, cost, etc.: | | | | | | | | | | |
| Value.......... | $1.61 | $1.75 | $2.38 | $2.66 | $2.31 | $3.64 | $4.13 | ........ | ........ | ....... |
| Cost............ | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | ........ | ........ | ....... |
| Profit or loss... | −4.71 | −3.90 | −2.65 | −4.37 | −1.94 | −10.32 | −6.51 | ........ | ........ | ....... |

[a] Nine plats, 1909 to 1913, inclusive.
[b] Two plats, 1909 to 1912, inclusive.
[c] Two plats, 1909 to 1913, inclusive.
[d] Birds destroyed the young wheat plants in the fall, and the plats were reseeded to spring wheat.

Winter wheat was a total failure at the Garden City station every year from 1909 to 1913, inclusive. During these years no method of tillage overcame the unfavorable conditions. As no cultivated land borders on the station, pests, such as rabbits, grasshoppers, and birds, often reduce the yields as much as and sometimes more than unfavorable climatic conditions. Green manuring has never produced profitable yields. Early fall plowing, late fall plowing, and summer tillage produced profitable yields in 1915, while subsoiling yielded a profit in 1914. Disked corn and potato ground and listing were profitable in 1914 and 1915. No method has averaged a profit for the seven years. The average losses per acre range from $1.94 on disked corn and potato ground to $10.32 from green manuring.

### DALHART FIELD STATION.

The soil at Dalhart, Tex., is a sandy loam. In some respects it behaves like sand. In other respects it exhibits the characteristics of a heavy clay soil. Its water-holding capacity is comparatively limited. The crops appear, however, to be able to utilize its water to the depth of a normal root development.

At the Dalhart station the crop of winter wheat was totally destroyed by hail in 1910 and 1912, and these years are not used in the averages. In 1909, 1911, 1913, and 1916 no yields were produced from any of the methods. In 1914 all the methods, except summer tillage, produced profitable yields, but that is the only year when there were any profitable yields. When yields have been secured there have been no marked differences between the various methods. Drought and soil blowing in early spring have been the chief causes of failures and low yields. (Table XV.)

TABLE XV.—*Yield and cost of production of winter wheat by different methods at the Dalhart Field Station, 1909 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1909 | 1910 | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 0 | [a]H | 0 | [a]H | 0 | 10.0 | 8.3 | 0 | 3.1 |
| Late fall plowed: Winter wheat | 1 | 0 | H | 0 | H | 0 | 12.0 | 5.3 | 0 | 2.9 |
| Listed: Winter wheat | 1 | 0 | H | 0 | H | 0 | 10.0 | ...... | ...... | 2.5 |
| Disked: Corn | 3 | 0 | H | 0 | H | 0 | ...... | ...... | ...... | 0 |
| Green manured: | | | | | | | | | | |
| With rye | 4 | 0 | H | 0 | H | 0 | ...... | ...... | ...... | 0 |
| With peas[b] | 4 | 0 | H | 0 | H | 0 | ...... | ...... | ...... | 0 |
| Total or average | 8 | ...... | ...... | ...... | ...... | ...... | ...... | ...... | ...... | 0 |
| Summer tilled | 2 | 0 | H | 0 | H | 0 | [c]13.1 | [c]8.0 | [c]0 | 3.5 |
| Average of all 16 plats | ...... | ...... | ...... | ...... | ...... | ...... | [d]11.3 | [e]7.2 | [e]0 | 3.1 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Disked (3 plats). | Green manured (8 plats). | Summer tilled (2 plats). | Winter wheat (3 plats). | Corn (3 plats). |
| Yields of grain: | | | | | | | | |
| 1909 ......bushels.. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1910 ......do.... | [a]H | H | H | H | H | H | H | H |
| 1911 ......do.... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1912 ......do.... | [a]H | H | H | H | H | H | H | H |
| 1913 ......do.... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1914 ......do.... | 10.0 | 12.0 | 10.0 | ...... | ...... | 13.1 | 10.7 | ...... |
| 1915 ......do.... | 8.3 | 5.3 | ...... | ...... | ...... | 8.0 | [f]6.8 | ...... |
| 1916 ......do.... | 0 | 0 | ...... | ...... | ...... | 0 | [f]0 | ...... |
| Average | 3.1 | 2.9 | 2.5 | ...... | ...... | 3.5 | 2.9 | 0 |
| Crop value, cost, etc.: | | | | | | | | |
| Value | $2.17 | $2.03 | $1.75 | 0 | 0 | $2.45 | ...... | ...... |
| Cost | 6.32 | 5.65 | 5.03 | 4.25 | 13.96 | 10.64 | ...... | ...... |
| Profit or loss | −4.15 | −3.62 | −3.28 | −4.25 | −13.96 | −8.19 | ...... | ...... |

[a] H=Destroyed by hail.
[b] Cowpeas grown from 1908 to 1910; field peas grown since 1910.
[c] One plat in 1914, 1915, and 1916.
[d] Four plats in 1914.
[e] Three plats in 1915 and 1916.
[f] Two plats in 1915 and 1916.

## AMARILLO FIELD STATION.

The soil at Amarillo, Tex., is a heavy clay silt. It is of the type locally known as "tight land" or "short-grass land." While the evidence is not as complete as could be desired, it appears that the storage of water and the development of the feeding roots of the crop are interfered with by a comparatively impervious layer of soil in the third foot.

The results of eight years are available from Amarillo. The year 1910 was lost by reason of an enforced change in the location of the station. In four of the eight years the yields were fair and in four they were very poor. (Table XVI.)

TABLE XVI.—*Yield and cost of production of winter wheat by different methods at the Amarillo Field Station, 1908 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1908 | 1909 | 1910[1] | 1911 | 1912 | 1913 | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 14.3 | 0 | ...... | 3.5 | 7.2 | 1.3 | 23.0 | 24.4 | 3.6 | 9.7 |
| Late fall plowed: Winter wheat | 1 | 12.7 | 0 | ...... | 3.1 | 5.5 | 0 | 21.8 | 18.3 | 5.8 | 8.4 |
| Listed: Winter wheat | 1 | 15.3 | 0 | ...... | 2.2 | 5.7 | 1.2 | 14.2 | 22.2 | 6.8 | 8.5 |
| Subsoiled: Winter wheat | 1 | 16.5 | 0 | ...... | 1.2 | 3.3 | 1.3 | 19.3 | 19.7 | 4.5 | 8.2 |
| Disked: Corn | 2 | 11.7 | 0 | ...... | 1.2 | 10.4 | 2.0 | 16.3 | 11.5 | 3.6 | 7.1 |
| Green manured: | | | | | | | | | | | |
| With rye | 3 | 15.0 | 0 | ...... | 2.1 | 10.8 | 2.4 | 16.4 | 14.9 | 4.8 | 8.3 |
| With peas[2] | 3 | 12.7 | 0 | ...... | 2.2 | 10.9 | 2.7 | 16.9 | 11.8 | 3.9 | 7.6 |
| Total or average | 6 | 13.8 | ...... | ...... | 2.1 | 10.9 | 2.5 | 16.7 | 13.4 | 4.3 | 8.0 |
| Summer tilled | 2 | 16.9 | 2.9 | ...... | 4.8 | 12.8 | 4.3 | 22.4 | 15.7 | 5.3 | 10.6 |
| Average of all 14 plats | ........ | 14.2 | .4 | ...... | 2.5 | 9.5 | 2.3 | 18.3 | 15.7 | 4.6 | 8.4 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yields, values, etc. (average per acre). | Tillage treatment. | | | | | | | Previous crop. | |
|---|---|---|---|---|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Listed (1 plat). | Subsoiled (1 plat). | Disked (2 plats). | Green manured (6 plats). | Summer tilled (2 plats). | Winter wheat (4 plats). | Corn (2 plats). |
| Yields of grain: | | | | | | | | | |
| 1908 bushels | 14.3 | 12.7 | 15.3 | 16.5 | 11.7 | 13.8 | 16.9 | 14.7 | 11.7 |
| 1909 do | 0 | 0 | 0 | 0 | 0 | 0 | 2.9 | 0 | 0 |
| 1910[1] do | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| 1911 do | 3.5 | 3.1 | 2.2 | 1.2 | 1.2 | 2.1 | 4.8 | 2.5 | 1.2 |
| 1912 do | 7.2 | 5.5 | 5.7 | 3.3 | 10.4 | 10.9 | 12.8 | 5.4 | 10.4 |
| 1913 do | 1.3 | 0 | 1.2 | 1.3 | 2.0 | 2.5 | 4.3 | 1.0 | 2.0 |
| 1914 do | 23.0 | 21.8 | 14.2 | 19.3 | 16.3 | 16.7 | 22.4 | 19.6 | 16.3 |
| 1915 do | 24.4 | 18.3 | 22.2 | 19.7 | 11.5 | 13.4 | 15.7 | 21.2 | 11.5 |
| 1916 do | 3.6 | 5.8 | 6.8 | 4.5 | 3.6 | 4.3 | 5.3 | 5.2 | 3.6 |
| Average | 9.7 | 8.4 | 8.5 | 8.2 | 7.1 | 8.0 | 10.6 | 8.7 | 7.1 |
| Crop value, cost, etc.: | | | | | | | | | |
| Value | $6.79 | $5.88 | $5.95 | $5.74 | $4.97 | $5.60 | $7.42 | ........ | ........ |
| Cost | 6.32 | 5.65 | 5.03 | 7.03 | 4.25 | 13.96 | 10.64 | ........ | ........ |
| Profit or loss | .47 | .23 | .92 | −1.29 | .72 | −8.36 | −3.22 | ........ | ........ |

[1] The yields for 1910 are not used, as the station was moved that year.
[2] Cowpeas were grown from 1907 to 1911; field peas since 1911.

In 1909 winter wheat was a total failure at the Amarillo station from all methods except summer tillage, which produced 2.9 bushels per acre.

No method has shown any marked superiority over others in producing yields. The highest average yield, 10.6 bushels per acre by summer tillage, is 3.5 bushels greater than the lowest average yield, 7.1 bushels, on disked corn ground.

In 1908, 1914, and 1915 all methods except that of green manuring produced profitable yields, and in 1912 there was a profit on disked corn ground. With these exceptions none of the methods have been profitable. As an average for the eight years green manuring, summer tillage, and subsoiling have shown losses of $8.36, $3.22, and $1.29, respectively, while listing, disked corn ground, early fall plowing, and late fall plowing have shown profits of 92, 72, 47, and 23 cents, respectively.

### TUCUMCARI FIELD STATION.

The soil at the field station at Tucumcari, N. Mex., is a fine sand. Below the third foot the soil type changes to a loam and then to a clay. The soil drifts quite readily.

During the three years that winter wheat has been grown at this station the crop was a total failure once. In 1915 and 1916 the yields were so small that under no method did the yield of grain pay the cost of production. Drought at critical periods and soil blowing are the chief unfavorable factors. (Table XVII.)

TABLE XVII.—*Yields and cost of production of winter wheat by different methods at the Tucumcari Field Station, 1914 to 1916, inclusive.*

| Treatment and previous crop. | Number of plats averaged. | Yield per acre (bushels). | | | |
|---|---|---|---|---|---|
| | | 1914 | 1915 | 1916 | Average. |
| Early fall plowed: Winter wheat | 1 | 0 | 6.4 | 1.8 | 2.7 |
| Late fall plowed: Winter wheat | 1 | 0 | 7.0 | 0 | 2.3 |
| Summer tilled | 1 | 0 | 5.3 | 4.0 | 3.1 |
| Average of all 3 plats | | | 6.2 | 1.9 | 2.7 |

SUMMARY OF YIELDS AND DIGEST OF COST.

| Yield, values, etc. (average per acre). | Tillage treatment. | | | Previous crop. |
|---|---|---|---|---|
| | Early fall plowed (1 plat). | Late fall plowed (1 plat). | Summer tilled (1 plat). | Winter wheat (2 plats). |
| Yield of grain: | | | | |
| 1914 bushels | 0 | 0 | 0 | 0 |
| 1915 do. | 6.4 | 7.0 | 5.3 | 6.7 |
| 1916 do. | 1.8 | 0 | 4.0 | .9 |
| Average | 2.7 | 2.3 | 3.1 | 2.5 |
| Crop value, cost, etc.: | | | | |
| Value | $1.89 | $1.61 | $2.17 | |
| Cost | 6.32 | 5.65 | 10.64 | |
| Profit or loss | −4.43 | −4.04 | −8.47 | |

## GENERAL DISCUSSION OF RESULTS.

In the preceding pages data have been presented and briefly discussed separately for each station without reference to results at other stations. In the following pages the data are considered from a more general standpoint. Table XVIII will assist in this study.

TABLE XVIII.—*Comparison of the average yields and profit or loss on the production of winter wheat by different methods at thirteen stations in the Great Plains area.*

| Statement of data. | Number of years averaged. | Method of tillage. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Early fall plowed.[a] | Late fall plowed.[a] | Listed. | Subsoiled. | Disked. | Green manured. | Summer tilled. |
| Yields per acre (bushels): | | | | | | | | |
| Judith Basin | 7 | 18.2 | 18.0 | 17.2 | 18.3 | [b]20.2 | [c]24.4 | 25.7 |
| Huntley | 4 | [b]17.2 | [b]18.9 | [b]18.5 | [b]19.0 | 25.8 | 30.6 | 39.4 |
| Belle Fourche | 8 | 12.4 | 12.7 | 14.3 | 12.1 | ........ | ........ | 23.1 |
| Ardmore | 3 | 19.7 | 19.0 | 19.7 | 22.6 | 22.2 | 21.0 | 25.5 |
| Archer | 3 | 10.7 | 10.0 | 8.9 | 8.9 | [d]13.6 | [d]13.8 | 12.6 |
| Scottsbluff | 5 | 9.1 | 5.4 | [e]3.8 | [d]13.7 | 15.4 | 15.3 | 20.6 |
| North Platte | 5 | 16.7 | 15.4 | ........ | ........ | 19.5 | 21.5 | 21.6 |
| Akron | 7 | 13.7 | 13.3 | 14.2 | 12.0 | 19.7 | 16.8 | 23.1 |
| Hays | 9 | 17.6 | 11.0 | 19.2 | 19.6 | 15.4 | 17.0 | 22.7 |
| Garden City | 7 | 2.3 | 2.5 | 3.4 | 3.8 | 3.3 | 5.2 | 5.9 |
| Dalhart | 6 | 3.1 | 2.9 | [f]2.5 | ........ | [b]0 | [b]0 | 3.5 |
| Amarillo | 8 | 9.7 | 8.4 | 8.5 | 8.2 | 7.1 | 8.0 | 10.6 |
| Tucumcari | 3 | 2.7 | 2.3 | ........ | ........ | ........ | ........ | 3.1 |
| Average | ........ | 11.8 | 10.8 | 11.8 | 13.8 | 14.7 | 15.8 | 18.3 |
| Average for the 9 stations at which all methods are used | ........ | 13.1 | 11.8 | 12.6 | 14.0 | 15.9 | 16.9 | 20.7 |
| Profit or loss (—) per acre: | | | | | | | | |
| Judith Basin | 7 | $6.42 | $6.95 | $7.01 | $5.78 | [b]$9.89 | [c]$3.12 | $7.35 |
| Huntley | 4 | [b]5.72 | [b]7.58 | [b]7.92 | [b]6.27 | 13.81 | 7.46 | 16.94 |
| Belle Fourche | 8 | 2.36 | 3.24 | 4.98 | 1.44 | ........ | ........ | 5.53 |
| Ardmore | 3 | 7.47 | 7.65 | 8.76 | 8.79 | 11.29 | .74 | 7.21 |
| Archer | 3 | 1.17 | 1.35 | 1.20 | — .80 | [d]5.27 | [d]— 4.30 | —1.82 |
| Scottsbluff | 5 | .05 | —1.87 | [e]—2.37 | [d]2.56 | 6.53 | — 3.25 | 3.78 |
| North Platte | 5 | 5.37 | 5.13 | ........ | ........ | 9.40 | 1.09 | 4.48 |
| Akron | 7 | 3.27 | 3.66 | 4.91 | 1.37 | 9.54 | — 2.20 | 5.53 |
| Hays | 9 | 6.00 | 2.05 | 8.41 | 6.69 | 6.53 | — 2.06 | 5.25 |
| Garden City | 7 | —4.71 | —3.90 | —2.65 | —4.37 | —1.94 | —10.32 | —6.51 |
| Dalhart | 6 | —4.15 | —3.62 | [f]—3.28 | ........ | [b]—4.25 | [b]—13.96 | —8.19 |
| Amarillo | 8 | .47 | .23 | .92 | —1.29 | .72 | — 8.36 | —3.22 |
| Tucumcari | 3 | —4.43 | —4.04 | ........ | ........ | ........ | ........ | —8.47 |

[a] At Huntley and Judith Basin there is no difference in time of plowing. The plats at these stations designated as plowed "early" were plowed deep; those designated as "late" were plowed shallow.

[b] Three years. [c] Six years. [d] Two years. [e] One year. [f] Four years.

In this table the average yields at the several stations are grouped under different methods of preparation. The figures here given are taken from the tables showing details for each station.

Data in regard to yields and cost of production are also assembled in such a way as to show the profit or loss in dollars and cents per acre for the average crop by each method for which it has been computed at each station.

Table XVIII shows that at five of the stations (Judith Basin, Huntley, Belle Fourche, Ardmore, and North Platte) winter wheat has been grown at a profit by all the methods under trial. At two (Akron and Hays) all methods except green manuring have been profitable. At three (Garden City, Dalhart, and Tucumcari) none of the methods have produced profits. At two (Archer and Amarillo) early and late fall plowing, listing, and disked corn ground have been profitable, the other methods having produced losses. At Scottsbluff early plowing, subsoiling, disked corn ground and summer tillage have returned profits, while late fall plowing, listing, and green manuring have been unprofitable.

As an average for all the stations, early (deep) fall plowing has produced 1 bushel more per acre than late (shallow) fall plowing. The stations that have shown marked differences in the yields of these two methods are Huntley, Scottsbluff, North Platte, Hays, and Amarillo. At Huntley the difference has been in favor of shallow plowing on the average and in each year except 1915. At Scottsbluff, North Platte, Hays, and Amarillo the difference has been in favor of early fall plowing on the average and in each year except at Scottsbluff and North Platte in 1915, at Hays in 1907 and 1908, and at Amarillo in 1916. At Scottsbluff, North Platte, Hays, and Amarillo the profits from early fall plowing are greater, but at the other stations late plowing has been more profitable or has resulted in smaller losses, mainly because it is a less expensive method.

Listing, instead of plowing, wheat stubble after harvest and leveling the ridges preparatory to seeding has averaged 0.9 bushel per acre more than early plowing and 2.2 bushels more than late plowing at the 11 stations where this method has been tried. At five of these stations (Huntley, Belle Fourche, Akron, Hays, and Garden City) it has given higher yields than early fall plowing, and at six (Belle Fourche, Ardmore, Akron, Hays, Garden City, and Amarillo) it has given higher yields than late plowing. Being a cheaper method than plowing, it has been more profitable than early plowing at all of the stations and more profitable than late plowing at all except Archer. At Scottsbluff, Garden City, and Dalhart winter wheat is grown at a loss by this method. At Hays and Amarillo the profits from this method are larger than from any other method under trial.

Subsoiling, as compared with fall plowing similar wheat stubble without subsoiling, has given higher yields at Huntley, Ardmore, Hays, and Garden City. At these stations the average increase due to subsoiling has been more than enough to pay for the extra cost. At Judith Basin and Belle Fourche the yields from the two methods have averaged practically the same, while at Archer, Akron, and Amarillo the differences in favor of plowing without subsoiling are 1.8, 1.7, and 1.5 bushels, respectively. At Scottsbluff, where only two years' results are available for subsoiling, the average yield and average profit are in favor of subsoiling.

Disked corn ground has given consistently high yields. At 6 of the 11 stations where this method has been practiced it has averaged higher yields than any of the other continuous-cropping methods. Because of the uniformly high yields secured and because of the low cost of preparation, disked corn ground has shown the largest profit at all of the stations except at Huntley, where summer tillage shows $3.13 more profit, at Hays, where listing and subsoiling have netted $1.98 and 18 cents more, respectively, and at Amarillo, where there is a difference of 20 cents in favor of listing. At Garden City, where none of the methods have been profitable, the smallest loss is from disked corn ground, but at Dalhart the loss on disked corn ground has been greater than from any of the other methods except green manuring and summer tillage. The realization of these profits on disked corn ground depends, of course, upon the successful growth of corn as a general farm crop in competition with other crops.

Summer tillage has given the highest average yield of any method under trial at all of the stations except North Platte and Archer, where both green manuring with rye and disked corn ground have averaged higher. As an average for the nine stations at which all of the various methods are practiced, the yield from summer tillage has been 4.8 bushels more than the yield from disked corn ground, the highest yielding of the continuous-cropping methods, and 3.8 bushels more than from green manuring. However, at only one station, Huntley, has summer tillage shown the greatest profit of any of the methods. Summer tillage requires the use of the land two years to produce one crop, and an extra amount of cultivation is necessary to keep the ground free from weeds during the fallow period; consequently, it has the highest acre cost of any method under trial except green manuring. Except at Huntley the increase in yield from this method has been more than offset by the increased cost of production over the cost of the best continuous-cropping methods. It does, however, show a profit at all but five of the stations, and only at Archer and Amarillo has it failed to net a profit when any of the other methods have returned a profit.

Green manuring is the most expensive method under trial. It resembles a fallow in that it requires the use of the land for two years for the production of one harvested crop, with the added expense of seed and seeding. There is a saving in cultivation during the spring while the crop is growing, but this is offset by the necessity of plowing to turn the crop under and is not sufficient to make up for the cost of seed and seeding. Increases in yields have not been commensurate with the cost of producing them. At none of the stations except Archer and North Platte have the yields following any green-manure crop exceeded those from summer tillage. The net returns from green manuring have not been as great as from any of the other methods at any of the stations. A profit has been realized from green manuring at the Judith Basin, Huntley, Ardmore, and North Platte stations. At the other stations the yields from this method have not been sufficient to pay the cost of producing them, and the losses have been greater than the losses from any other method.

It is hardly fair to charge the whole expense of green manuring to the one crop that immediately follows it, as is done. This method should have a cumulative effect in building up the soil or remedying its deficiency in organic matter. The available evidence is that on normal soils on the Great Plains, at least in the first years of the work, little effect is shown on other than the first crop. This effect is that of a fallow to the extent that the green manure approaches a fallow in the storage of water during the period after the crop is plowed under.

### COMPARISON OF WINTER WHEAT WITH SPRING WHEAT.

Table XIX shows the average yields and profit or loss for winter wheat and spring wheat by the different methods under which both of these crops are grown at the 13 stations. This table also gives the average yield and average profit or loss for all of the methods used with each of these crops at each of the stations. The yields from the various methods are comparable for the two crops at each station. The figures used in computing the profit or loss for spring wheat are the same as those used in Table IV in United States Department of Agriculture Bulletin No. 214, entitled "Spring Wheat in the Great Plains Area." Because winter wheat is seeded in the fall, the cost of preparing the ground by the various methods is less than for spring wheat.

At the North Platte, Akron, and Hays stations winter wheat has been distinctly more productive than spring wheat under all methods tried. The greatest differences between the yields of winter wheat and spring wheat have been secured at Hays, where the differences in favor of winter wheat range from 8.6 bushels per acre on disked corn ground to 15.7 bushels on summer tillage. At Tucumcari the yields of spring wheat have been greater than those of winter wheat from the methods under which both crops are grown. The average yield from all the methods used with both crops is decidedly in favor of winter wheat at Huntley and somewhat in favor of winter wheat at Belle Fourche, Scottsbluff, and Amarillo. At the other stations the average yield of spring wheat is slightly greater than the average yield of winter wheat.

The average yield from summer tillage has been decidedly in favor of winter wheat at Judith Basin, Huntley, Belle Fourche, Scottsbluff, North Platte, Akron, and Hays. At Garden City, Dalhart, and Amarillo the average has been slightly in favor of spring wheat, while at Tucumcari it has been decidedly in favor of spring wheat. At Ardmore and Archer the average yields from summer tillage have been practically equal for the two crops.

Table XIX.—*Comparison of the average yields of spring wheat and winter wheat by different methods at thirteen stations in the Great Plains area.*

| Statement of data. | Judith Basin (7 years). | Huntley (4 years). | Belle Fourche (8 years). | Ardmore (3 years). | Archer (3 years). | Scottsbluff (5 years). | North Platte (5 years). | Akron (7 years). | Hays (9 years). | Garden City (7 years). | Dalhart (6 years). | Amarillo (8 years). | Tucumcari (3 years). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Yield per acre (bushels).* | | | | | | | | | | | | | |
| Early fall plowed: | | | | | | | | | | | | | |
| Winter wheat | 18.2 | 17.2 | 12.4 | 19.7 | 10.7 | 9.1 | 16.7 | 13.7 | 17.6 | 2.3 | 3.1 | 9.7 | 2.7 |
| Spring wheat | 19.7 | 17.8 | 13.1 | 22.3 | 11.2 | 8.5 | 11.6 | 9.1 | 5.4 | 3.8 | 3.8 | 8.4 | 6.8 |
| Listed: | | | | | | | | | | | | | |
| Winter wheat | 17.2 | 18.5 | 14.3 | 19.7 | 8.9 | 3.8 | ...... | 14.2 | 19.2 | 3.4 | 2.5 | 8.5 | ...... |
| Spring wheat | 20.1 | 17.6 | 15.0 | 16.8 | 10.0 | 5.3 | ...... | 10.1 | 6.5 | 5.3 | 5.4 | 7.0 | ...... |
| Subsoiled: | | | | | | | | | | | | | |
| Winter wheat | 18.3 | 19.0 | 12.1 | 22.6 | 8.9 | 13.7 | ...... | 12.0 | 19.6 | 3.8 | ...... | 8.2 | ...... |
| Spring wheat | 20.6 | 17.0 | 14.0 | 18.7 | 10.6 | 8.3 | ...... | 8.4 | 5.8 | 4.7 | ...... | 7.5 | ...... |
| Disked: | | | | | | | | | | | | | |
| Winter wheat | 20.2 | 25.8 | ...... | 22.2 | 13.6 | 15.4 | 22.1 | 19.7 | 15.4 | 3.3 | 0 | 7.1 | ...... |
| Spring wheat | 26.2 | 24.6 | ...... | 24.2 | 15.9 | 14.2 | 12.1 | 12.2 | 6.8 | 5.7 | 2.1 | 7.0 | ...... |
| Green manured: | | | | | | | | | | | | | |
| Winter wheat | 24.4 | 30.6 | ...... | 21.0 | 13.8 | 15.3 | ...... | 16.8 | ...... | ...... | 0 | 8.0 | ...... |
| Spring wheat | 21.0 | 26.4 | ...... | 24.3 | 16.2 | 15.6 | ...... | 11.9 | ...... | ...... | .3 | 8.5 | ...... |
| Summer tilled: | | | | | | | | | | | | | |
| Winter wheat | 25.7 | 39.4 | 23.1 | 25.5 | 12.6 | 20.6 | 21.6 | 23.1 | 22.7 | 5.9 | 3.5 | 10.6 | 3.1 |
| Spring wheat | 21.6 | 26.6 | 18.2 | 25.5 | 12.5 | 16.6 | 15.6 | 16.0 | 7.0 | 7.3 | 6.2 | 11.5 | 8.6 |
| Average: | | | | | | | | | | | | | |
| Winter wheat | 20.7 | 25.1 | 15.5 | 21.8 | 11.4 | 13.0 | 20.1 | 16.6 | 18.9 | 3.7 | 1.8 | 8.7 | 2.9 |
| Spring wheat | 21.5 | 21.7 | 15.1 | 22.0 | 12.7 | 11.4 | 13.1 | 11.3 | 6.3 | 5.4 | 3.6 | 8.3 | 7.7 |
| *Profit or loss (—) per acre.* | | | | | | | | | | | | | |
| Early fall plowed: | | | | | | | | | | | | | |
| Winter wheat | $6.42 | $5.72 | $2.36 | $7.47 | $1.17 | $0.05 | $5.37 | $3.27 | $6.00 | —$4.71 | —$4.15 | $0.47 | —$4.43 |
| Spring wheat | 7.23 | 5.90 | 2.61 | 9.05 | 1.28 | — .61 | 1.56 | — .19 | —2.78 | — 3.90 | — 3.90 | — .68 | — 1.80 |
| Listed: | | | | | | | | | | | | | |
| Winter wheat | 7.01 | 7.92 | 4.98 | 8.76 | 1.20 | —2.37 | ...... | 4.91 | 8.41 | — 2.65 | — 3.28 | .92 | ...... |
| Spring wheat | 8.52 | 6.77 | 4.95 | 6.21 | 1.45 | —1.84 | ...... | —1.52 | —1.00 | — 1.84 | — 1.77 | — .65 | ...... |
| Subsoiled: | | | | | | | | | | | | | |
| Winter wheat | 5.78 | 6.27 | 1.44 | 8.79 | — .80 | 2.56 | ...... | 1.37 | 6.69 | — 4.37 | ...... | —1.29 | ...... |
| Spring wheat | 7.25 | 4.73 | 2.63 | 5.92 | .25 | —1.36 | ...... | —1.29 | —3.11 | — 3.88 | ...... | —1.92 | ...... |
| Disked: | | | | | | | | | | | | | |
| Winter wheat | 9.89 | 13.81 | ...... | 11.29 | 5.27 | 6.53 | 11.22 | 9.54 | 6.53 | — 1.94 | — 4.25 | .72 | ...... |
| Spring wheat | 13.59 | 12.47 | ...... | 12.19 | 6.38 | 5.19 | 3.72 | 3.79 | .01 | — .76 | — 3.28 | .15 | ...... |
| Green manured: | | | | | | | | | | | | | |
| Winter wheat | 3.12 | 7.46 | ...... | .74 | —4.30 | —3.25 | ...... | —2.20 | ...... | ...... | —13.96 | —8.36 | ...... |
| Spring wheat | .09 | 3.87 | ...... | 2.40 | —3.27 | —3.69 | ...... | —6.28 | ...... | ...... | —14.40 | —8.66 | ...... |
| Summer tilled: | | | | | | | | | | | | | |
| Winter wheat | 7.35 | 16.94 | 5.53 | 7.21 | —1.82 | 3.78 | 4.48 | 5.53 | 5.25 | — 6.51 | — 8.19 | —3.22 | — 8.47 |
| Spring wheat | 3.62 | 7.12 | 1.24 | 6.35 | —2.75 | .12 | — .58 | — .30 | —6.60 | — 6.39 | — 7.16 | —3.45 | — 5.48 |
| Average: | | | | | | | | | | | | | |
| Winter wheat | 6.60 | 9.69 | 3.58 | 7.38 | .12 | 1.22 | 7.02 | 3.74 | 6.58 | — 4.04 | — 6.77 | —1.79 | — 6.45 |
| Spring wheat | 6.72 | 6.81 | 2.86 | 7.02 | .56 | — .37 | 1.57 | — .97 | —2.70 | — 3.35 | — 5.09 | —2.54 | — 3.64 |

As an average for all the methods, winter wheat has proved more profitable at Huntley, Belle Fourche, Ardmore, Scottsbluff, North Platte, Akron, and Hays. Spring wheat has been slightly more profitable at Judith Basin and Archer. At the remaining stations an average of all the methods shows a loss for both crops. At Amarillo the average loss is less for winter wheat, while at Garden City, Dalhart, and Tucumcari it is greater. The greatest differences between the net returns from the two crops are $9.28 at Hays, $5.45 at North Platte, and $4.71 at Akron, all being in favor of winter wheat. At only 3 of the 13 stations (Garden City, Dalhart, and Tucumcari) are the returns from summer tillage greater for spring wheat than for winter wheat. At all the other stations winter wheat shows larger net returns after summer tillage than spring wheat.

These results indicate that winter wheat rather than spring wheat should be grown under conditions similar to those existing at Huntley, North Platte, Akron, and Hays, and probably at Scottsbluff, Belle Fourche, and Judith Basin. At Archer and Ardmore, where the results are available for only three years, the differences are so small that another year's work might alter the averages considerably. At Garden City, Dalhart, and Tucumcari neither of the crops has returned a profit by any method. At Amarillo, under the methods which have yielded profits, those from winter wheat have been greater than those from spring wheat.

## CONCLUSIONS.

These conclusions apply only to the yields of winter wheat as affected by the cropping and cultivation of the one year immediately preceding growth.

(1) Some seasons are so unfavorable as to result in failure of the winter-wheat crop without regard to the cultural methods under investigation. Extremely unfavorable climatic conditions can not be overcome by cultural methods.

(2) It is only in those seasons when the rainfall deficit is so small that it can be overcome by moisture stored in the soil that the cultural methods under investigation have shown important effects upon yields.

(3) When the differences in the values of the yields are less than the differences in cost of production, then cost becomes the determining factor.

(4) Some soils, even in regions of profitable winter-wheat production, show little response to cultural methods.

(5) Reducing the cost of production has in most cases in these investigations proved a more important factor in determining profits than increasing the yields by cultural methods.

(6) The average difference in yields between early (deep) and late (shallow) fall plowing is 1 bushel per acre. At most stations the difference is small, while at others the advantage of one over the other depends on the season. At Scottsbluff, North Platte, Hays, and Amarillo the differences are rather consistently in favor of early plowing, and this method is more profitable at these stations. At the other stations late plowing has netted larger returns.

(7) Furrowing with a lister after harvest and leveling the ridges preparatory to seeding have resulted in an average increase of 0.9 bushel over early plowing and 2.2 bushels over late plowing. As it is a cheaper method of preparation than plowing, it has consequently been more profitable. At Hays and Amarillo it has been the most profitable method.

(8) Subsoiling has increased the yields over plowing without subsoiling at 5 of the 10 stations at which it has been studied. At these stations it has been more profitable than ordinary plowing. At the other stations it has been the least profitable of the continuous-cropping methods. It has not shown any value in overcoming drought.

(9) Disked corn ground has given consistently high yields. This, together with the low cost of preparation, has resulted in this method showing the highest average net returns of any of the methods at all of the 11 stations where it has been tried except at Huntley and Amarillo. These profits are based on the assumption that the corn crop was so utilized as to pay for the cost of producing it.

(10) Summer tillage has given the highest average yields of any method under trial at 11 of the 13 stations. However, on account of its high cost, due to extra labor and alternate-year cropping, it has not netted the largest returns except at Huntley.

(11) Green manuring is the most expensive method under investigation. It has given the smallest net returns of any of the methods at all of the stations except Huntley, where the profit from it is slightly greater than from either fall plowing or subsoiling.

(12) In comparison with spring wheat, winter wheat shows a greater response to summer tillage and is the more profitable crop to grow on land so prepared. This appears to be true at all stations studied except possibly Garden City, Dalhart, and Tucumcari, where large average losses attend the growth of either crop.

In the average of all methods by which the crops are grown winter wheat has a marked advantage over spring wheat, both in yields and profits per acre, at North Platte, Akron, and Hays in the central portion of the Great Plains and at Huntley, Mont. At the other stations, where either crop can be grown profitably, the average differences in favor of either are not great enough to be conclusive from the evidence at hand.

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UNITED STATES DEPARTMENT OF AGRICULTURE
**BULLETIN No. 596**
Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

Washington, D. C. PROFESSIONAL PAPER December 13, 1917

# FEEDING DRIED PRESSED POTATOES TO SWINE.

By Frank G. Ashbrook, *Junior Animal Husbandman in Swine Feeding and Breeding*, and R. E. Gongwer, *Scientific Assistant in Swine Investigations, Animal Husbandry Division.*

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## DRIED PRESSED POTATO.

Two investigators in the United States Department of Agriculture, William Stuart, of the Bureau of Plant Industry, and H. C. Gore, of the Bureau of Chemistry, have been studying the potato situation in the United States for the purpose of determining a suitable way to dispose of surplus potatoes. The dried pressed potato used in the feeding experiments was manufactured at the Government Experimental Farm, Arlington, Va. The following analysis of the feed shows that it is rich in carbohydrates, mostly starch, and poor in fat, protein, and ash ingredients.

*Chemical analysis of dried pressed potato used in experimental work.*

| Moisture. | Ash. | Ether extract. | Protein. | Crude fiber. | Nitrogen-free extract. |
|---|---|---|---|---|---|
| *Per cent.*<br>11.97 | *Per cent.*<br>0.89 | *Per cent.*<br>2.10 | *Per cent.*<br>2.19 | *Per cent.*<br>1.97 | *Per cent.*<br>80.88 |

## THE FEEDING EXPERIMENT.

The Animal Husbandry Division having been requested to cooperate in determining the value of dried pressed potato as a feed for swine, decided, after careful consideration as to the probable importance of the work, to carry on an extended feeding test at its farm at Beltsville. Five tons of dried pressed potato, manufactured at the Arlington farm, were shipped to the Beltsville farm for this purpose.

The experiment was conducted to determine (1) the value of dried pressed potato in a ration for fattening hogs when supplemented by feeds rich in protein, (2) the effect of dried pressed potato on the quality of meat produced.

### METHODS AND RATIONS.

The experimental feeding was started September 12, 1916, and continued 56 days, ending November 7, 1916. The animals selected for the work were 12 high-grade Berkshire pigs between 5 and 6 months of age, averaging approximately 150 pounds in weight, and quite uniform in age, quality, breeding, and weight. (See fig. 1.) The pigs were taken off pasture and put in the dry lot a week before the experiment began. They were confined in a permanent hog house and arranged into pens of three pigs each. These pens had cork-brick floors and measured 6 feet by 7½ feet. Attached thereto were outside runs made of concrete and measuring 7 feet by 39 feet. Prior to the experiment the ration fed to these pigs consisted of 5 parts corn

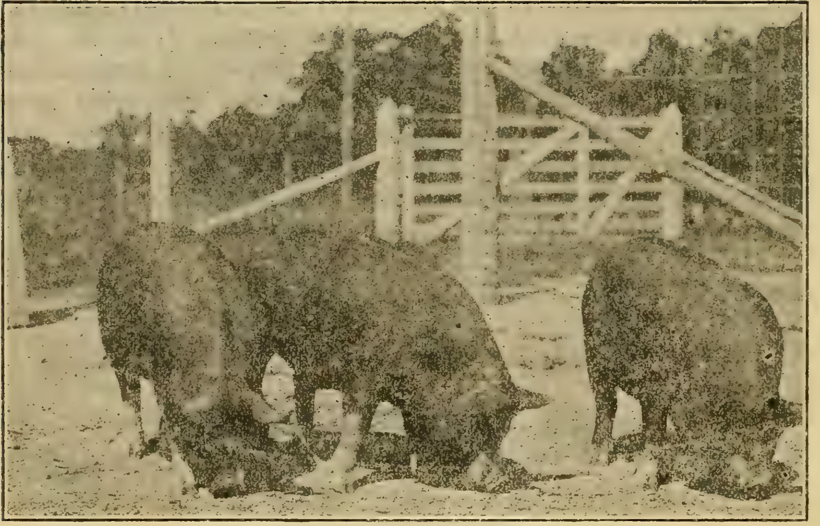

FIG. 1.—Type of hogs used in experimental feeding.

meal, 4 parts middlings, and 1 part tankage. The lots and rations for the experimental feeding were as follows:

Lot I (check lot).—6 parts corn meal, 1 part tankage.

Lot II.—6 parts dried pressed potato, 1 part tankage.

Lot III.—6 parts dried pressed potato, 1 part linseed-oil meal (old process).

Lot IV.—6 parts dried pressed potato, 1 part fish meal.[1]

The lots were fed three times daily (7 a. m., 11.30 a. m., and 4.30 p. m.). For each meal the feed for each lot was weighed and put into a bucket with a sufficient amount of water to make a thick slop, this being done about half an hour before feeding, so as to allow time to soak. Raw steam was turned into each bucket of feed for a few minutes just after the feed was mixed to facilitate the soaking. A fresh supply of water was given to the pigs about the middle of the forenoon. The animals were weighed on the scales located inside the permanent hog house. Individual weights were taken for three consecutive days (one day previous to the beginning of the experiment and each of the first two days of the experiment). The average of the three weights was taken as the weight of the second day, or the beginning of the experiment. The final division into lots followed the first weighing, which was on the day previous to the beginning of the experiment proper. Individual weights were taken every Tuesday thereafter until the conclusion of the experiment.

### COMPOSITION OF RATIONS.

Following are the analyses of the dried pressed potato rations as made by the Bureau of Chemistry, United States Department of Agriculture:

*Chemical composition of dried potato rations.*

| Ration. | Moisture. | Ash. | Ether extract. | Protein. | Crude fiber. | Nitrogen-free extract. |
|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| Dried pressed potato and tankage | 11.83 | 3.04 | 0.80 | 11.03 | 2.29 | 71.01 |
| Dried pressed potato and oil meal | 11.91 | 1.65 | .67 | 5.96 | 2.98 | 76.83 |
| Dried pressed potato and fish meal | 10.96 | 4.04 | 2.87 | 13.09 | 1.85 | 67.19 |

### RESULTS OF THE FEEDING.

The pigs in all of the lots ate well and regularly, and not one went off feed during the test. Small quantities of feed were left in the troughs after feeding time, but this was due to the fact that the pigs were given a little more than they could conveniently consume. Dried pressed potato is rather bulky, and it is difficult to judge exactly the right amount that will be cleaned up by the pigs at one feed. At the beginning of the test the amount fed was 2 pounds per head per day. This, of course, was a very small amount of feed for 150-pound pigs, but they were given this small portion because this method of gradually starting them on a feed tends to keep the appetite keen, and the chances of going off feed are very much lessened. It also gives the pigs a better chance to cultivate an appetite for a new feed. One fact is evident from the figures given in the next table, namely, that the dried pressed potato rations were palatable and eaten readily by the pigs, since all those in the potato lots consumed an average daily ration of 5½ pounds.

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[1] Fish meal is a very effective supplement to a grain ration for pigs. They are extremely fond of it and make rapid and economical gains on such a ration. Those who wish to obtain further information on the subject of feeding fish meal to live stock may consult United States Department of Agriculture Bulletins 378, "Fish Meal, Its Use as a Stock and Poultry Feed," and 610, "Fish Meal as a Feed for Swine," which may be had from the Superintendent of Documents, Washington, D. C., at the price of 5 cents each.

TABLE I.—*Results of feeding 4 lots of 3 pigs on various feeds during fattening period, Sept. 12, to Nov. 7, 1916 (56 days).*

| Data. | Lot I (check). | Lot II. | Lot III. | Lot IV. |
|---|---|---|---|---|
| | Fed 6 parts corn meal, 1 part tankage. | Fed 6 parts dried pressed potato, 1 part tankage. | Fed 6 parts dried pressed potato, 1 part oil meal. | Fed 6 parts dried pressed potato, 1 part fish meal. |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| Average initial weight | 153.33 | 153.33 | 150.00 | 154.33 |
| Average final weight | 242 | 198.33 | 206.33 | 228.66 |
| Average gain per pig | 87.77 | 45.00 | 51.33 | 74.33 |
| Average daily gain | 1.57 | .80 | .91 | 1.32 |
| Total feed | 1,072 | 939 | 900.5 | 956.5 |
| Pounds fed per 100 pounds gain | 403 | 695 | 584 | 428 |
| Daily feed per 100 pounds live weight | 3.23 | 3.16 | 2.93 | 2.91 |
| Average daily feed | 6.4 | 5.5 | 5.3 | 5.7 |

All the pigs were in good, thrifty, and growing condition when the experiment began, and they maintained good condition and health during the progress of the test. A study of the table will show that lot 1 (check) excels all the others with respect to rate of gains, amount of feed consumed to produce 100 pounds of gain, and the average final weight. This lot of pigs was the largest and growthiest of any of the lots in the experiment. They were heavy feeders and returned good gains for the amount of feed consumed. These pigs consumed a daily ration of 6.4 pounds, made a daily gain of 1.57 pounds, and required 403 pounds of feed to produce 100 pounds of gain.

The lot receiving dried pressed potato and fish meal (Lot IV) was a very close second to the check lot. The figures, of course, show greater advantages in favor of the check lot than were apparent to the eye. Both these lots maintained tiptop condition throughout the experiment and carried a very high degree of finish. There was

13 pounds difference in favor of the hogs in the check lot at the close of the test. The pigs in Lot IV were evidently as heavy feeders as those in the check lot, but it is impossible for pigs to consume very large amounts of the dried pressed potato on account of the bulkiness of the feeds. The pigs in Lot IV consumed a daily ration of 5.7 pounds, made a daily gain of 1.32 pounds, and required 428 pounds of feed to produce 100 pounds of gain.

The pigs in Lot III, receiving dried pressed potato and oil meal, consumed less feed than any other lot in the experiment. It might be concluded from this that the ration was the least palatable and least efficient of any of the rations fed. This, however, is not true, because the pigs in Lot II, receiving dried pressed potato and tankage, ate more feed than the pigs receiving dried pressed potato and oil meal, but made smaller gains. This tends to prove that the potato ration containing oil meal is more efficient in producing gains than the potato ration containing tankage, although the pigs ate less of the potato and oil-meal feed. Furthermore, the pigs in Lot III possessed a higher degree of finish than the potato and tankage pigs (Lot II), although they were not equal to the potato and fish-meal pigs (Lot IV) in this respect. The pigs in Lot III consumed a daily ration of 5.3 pounds, made a daily gain of 0.91 pound, and required 584 pounds of feed to produce 100 pounds of gain.

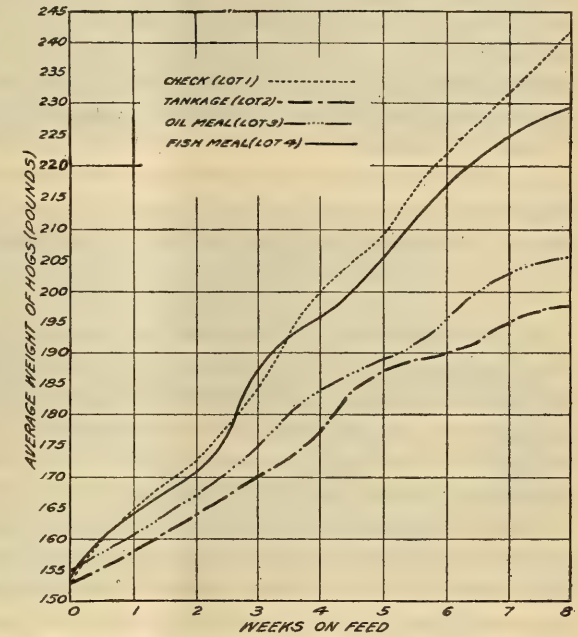


FIG. 2.—Average progressive weekly gains of each lot during feeding experiment.

The pigs in Lot II, which were fed dried pressed potato and tankage, consumed enough feed to put them in higher condition than they were in at the close of the feeding test. The showing that these pigs made can not be called poor, but it is evident that tankage is not as efficient a protein supplement to use with dried pressed potato as some of the other supplements used in this experiment. The pigs in Lot II returned a smaller amount of gain for the amount of feed consumed than any other lot. They consumed an average daily ration of 5.5 pounds, made an average daily gain of 0.8 pound, and required 695 pounds of feed to put on 100 pounds of gain.

Figure 2 shows graphically the weekly gains of each of the lots during the experimental feeding.

### SUMMARY OF FEEDING EXPERIMENT.

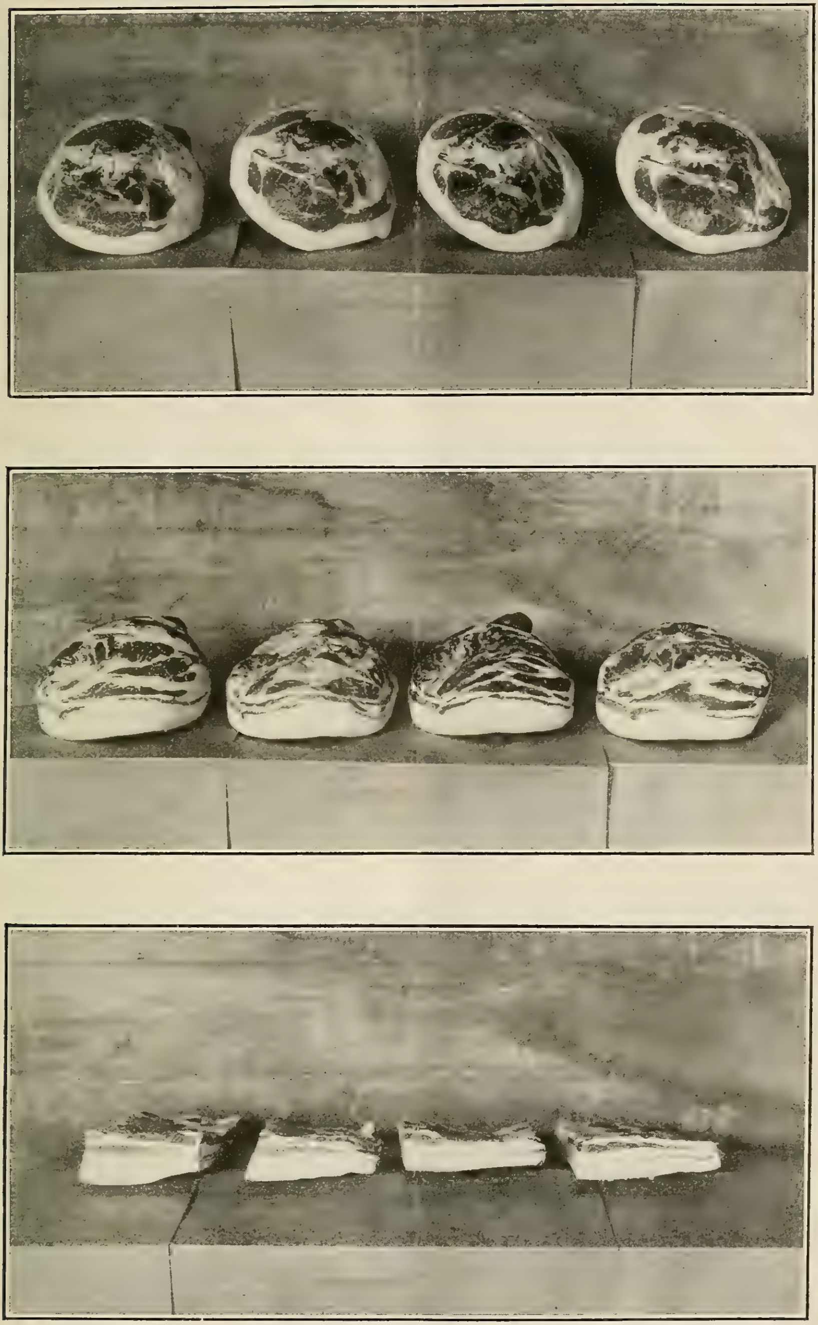
Judging from the results obtained from the feeding experiment, we are justified in concluding that dried pressed potato, when supplemented with a high-protein feed, is very efficient in producing rapid gains and a high finish when fed to swine. Although dried pressed potato is a rather bulky feed, it has been demonstrated that pigs are able to consume a sufficient quantity to lay on good gains. Mixing or soaking with water for 15 or 20 minutes before feeding has proved to be the best method of feeding dried pressed potato. To give the best results, dried pressed potato must be fed in combination with other feeds in which the percentage of protein is high.

## CARCASS TEST.

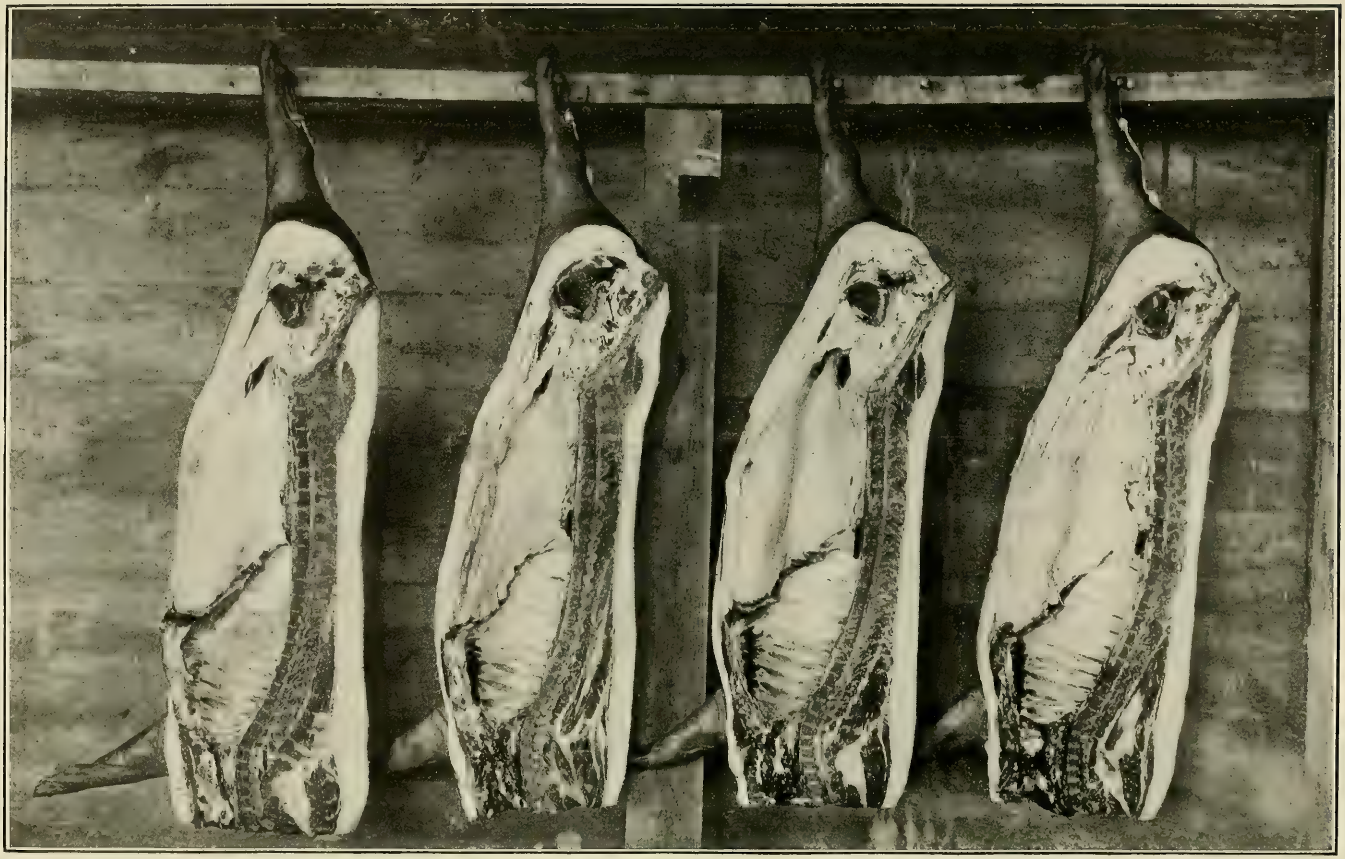
At the conclusion of the feeding experiment the weather was quite warm, and as it was necessary to kill the hogs " country style," they were held one week until cold weather. During this interval the ration of each lot was continued exactly the same as it had been during the feeding experiment, hence this delay would have no effect upon the quality of the carcass.

Twenty-four hours previous to killing, the hogs had access to nothing but water, thus removing much of the feed from the stomach and intestines. Individual weights were obtained immediately before slaughtering, and the average of these weights for each lot is recorded in the table below as the " Weight at killing time." The other data in the table were ascertained as soon as possible after slaughtering, the work being done as rapidly as was consistent with accuracy in order to minimize loss in weight through drying. The firmness of the flesh and fat was noted at this time, and again next morning after the carcass had cooled overnight at a freezing temperature.

Four hogs, the heaviest from each of the four lots, were reserved for the carcass demonstration to determine the quality of the flesh and fat, and if possible the degree of finish in each one. The carcasses were divided into the regular meat cuts in as nearly a uniform manner as was possible. The fresh pork from each hog was eaten by individuals who were ignorant of the feed that the hog had received, in order to test the flavor and cooking qualities of the meat. The lard was cut from the trimmings and rendered, as was also that



HAMS, SHOULDERS, AND SIDE BACON FROM HEAVIEST HOG IN LOTS I, II, III, AND IV, READING FROM LEFT TO RIGHT IN EACH CASE.



HALF CARCASSES OF HEAVIEST HOG IN LOTS I, II, III, AND IV, READING FROM LEFT TO RIGHT.

from the leaf, and observations made upon them. The data collected from the rendering of the lard are shown in Table III, which also gives some indication of the degree of finish obtained through these different feeds.

TABLE II.—*Slaughter data. Average of hogs in each lot.*

| | Lot I. | Lot II. | Lot III. | Lot IV. |
|---|---|---|---|---|
| | Fed 6 parts corn meal, 1 part tankage. | Fed 6 parts dried pressed potato, 1 part tankage. | Fed 6 parts dried pressed potato, 1 part oil meal. | Fed 6 parts dried pressed potato, 1 part fish meal. |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| Weight at killing time | 230 | 190 | 200 | 214 |
| Weight after bleeding and scraping | 219 | 181 | 189 | 204 |
| Weight of carcass | 186 | 148 | 156 | 172 |
| Weight of leaf lard | 6.69 | 5.06 | 5 | 5.12 |
| Weight of intestines and paunch | 16.44 | 18.81 | 20.19 | 17.56 |
| Weight of omentum | .81 | .62 | .62 | .69 |
| Weight of spleen | .31 | .25 | .31 | .44 |
| Weight of pluck | 8 | 6 | 6.87 | 7.12 |
| Dressing per cent | 80.9 | 78.0 | 78.0 | 80.4 |

It will be noted that the hogs fed corn meal (Lot I) showed the highest dressing percentage, with the dried pressed potato and fish meal (Lot IV) a very close second. The other two dried pressed potato lots had relatively low dressing percentages. This difference is largely explained by examining the weights of the intestines and paunch, in which the check lot (Lot I), although the largest hogs, had the lightest weight. Only 7.1 per cent of the live weight of the check hogs was contained in the digestive tract, while 9.3 per cent of the live weight of all the hogs fed on dried pressed potatoes was found here. These figures would seem to indicate that a ration consisting chiefly of dried pressed potato meal causes a large development of the digestive tract, due no doubt to the bulky nature of the feed.

In judging the firmness of the flesh and fat we used no instruments of precision, simply the eye and the sense of touch. In the freshly killed condition it was very easy to see that the fat in Lots II and IV was not as solid as that in the check lot (Lot I), and the feel of these three lots bore out their appearance. In Lot III, however, fed on dried pressed potato and oil meal, the fat was of a little firmer texture than in the other two lots fed on the potato feed, although it hardly seemed of the same consistency as Lot I. As to the quality of the flesh, we could note no difference. Upon cooling out thoroughly it was much more difficult to note any difference in the firmness of the fat.

On the whole it is impossible to say that dried pressed potato meal does not produce a fat equal for all purposes to that produced by corn meal. While we were able to note some little difference in hardness in favor of the lot fed on corn meal, that difference was so small as not to be noticed under average packing-house conditions. Dried pressed potato meal does not produce soft pork.

### QUALITY OF THE MEAT.

The four carcasses, one from each lot, which were reserved for the butchering test were found to be very similar in the development of the several parts. More variation was discovered among the three potato-fed hogs than there was between them as a group and the check hog. The fresh pork, principally the chops, was cooked and eaten by disinterested parties, as well as by the experimenters, and no difference in flavor or quality could be detected. In judging the degree of finish, the various cuts were examined as shown in Plate I. Excepting in the case of the bacon strips, little difference can be detected. Here it is indicated that the corn-fed hog is much the fattest.

An examination of half the carcass, observing chiefly the thickness of fat on the back, indicates that the hog from Lot I, the check lot, had much the heaviest covering in this region. It must be remembered, however, that the other three carcasses were not as large and that, relatively speaking, the covering shown on the hog from Lot III is almost as heavy (see Pl. II).

### LARD.

In order to judge more accurately the degree of finish, the lard was separated as previously noted and rendered under as nearly uniform conditions as possible. The results are given in the following table:

TABLE III.—*Lard data from largest hog in each lot.*

| Data. | Lot I. | | Lot II. | | Lot III. | | Lot IV. | |
|---|---|---|---|---|---|---|---|---|
| | Fed 6 parts corn meal, 1 part tankage. | | Fed 6 parts dried pressed potato, 1 part tankage. | | Fed 6 parts dried pressed potato, 1 part oil meal. | | Fed 6 parts dried pressed potato, 1 part fish meal. | |
| | Leaf lard. | Fat lard. | Leaf lard. | Fat lard. | Leaf lard. | Fat lard. | Leaf lard. | Fat lard. |
| Weight of cut lard..........pounds.. | 6.75 | 16.25 | 5.37 | 13 | 5 | 15.12 | 5.12 | 15,87 |
| Weight of rendered lard........do.... | 6.31 | 14.25 | 5 | 11.50 | 4.69 | 13.62 | 4.62 | 13.75 |
| Per cent of rendered lard.............. | 93.5 | 87.7 | 93 | 88.4 | 93.7 | 90 | 90.2 | 86.6 |
| Weight of carcass...........pounds.. | 193 | | 160 | | 163 | | 174 | |
| Per cent of rendered lard to carcass... | 10.65 | | 10.31 | | 11.23 | | 10.56 | |

This table bears out the previous indications that the hog fed on corn meal had the largest amount of fat, but it also shows that one hog fed dried pressed potato meal and linseed-oil meal produced relatively more fat in proportion to carcass. This was due to the fact that the latter hog was a little fatter and that the fat rendered out a higher percentage of lard. This last fact would also indicate a higher degree of finish, for as the lard contained a lower percentage of water the cells must have been more heavily engorged with fat. The hog fed on potato meal and fish meal was nearly as fat as the check hog. The carcass showing the poorest condition was that of the hog fed on potato meal and tankage, showing that this combination of feeds not only produced the smallest and most expensive gains, but that it also returned a carcass with the smallest proportion of fat. No difference in taste, odor, color, or consistency could be noticed in the rendered lard.

### CURED MEAT.

The hams, shoulders, and bacon sides from the heaviest hog in each lot, as pictured in Plate I, were cured and smoked. A mild brine cure was used according to the following formula: For each 100 pounds of meat 2 ounces saltpeter, 2 pounds brown sugar, and 7 pounds salt dissolved in enough water to cover the meat. The shoulders and bacon sides were removed at the end of five weeks and the hams after eight weeks of curing. The cured meat was allowed to drain 24 hours. After draining it was rubbed with pepper and smoked for six days with hickory wood. The results are shown in Tables IV and V.

TABLE IV.—*Weight variations in curing hams, shoulders, and side bacon.*

| Cut. | Lot No. | Green weight, Nov. 28. | Weight after curing, Jan. 23. | Weight after draining, Jan. 24. | Weight after smoking, Jan. 30. | Net gain (+) or loss (−) in weight. |
|---|---|---|---|---|---|---|
| | | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* | *Pound.* |
| Hams | Lot I | 17.00 | 18.12 | 17.94 | 16.75 | − 0.25 |
| | do | 13.81 | 15.00 | 14.81 | 13.69 | − .12 |
| | Lot II | 13.75 | 14.81 | 14.62 | 13.56 | − .19 |
| | do | 16.31 | 17.50 | 17.31 | 16.19 | − .12 |
| | Lot III | 13.87 | 14.56 | 14.44 | 13.50 | − .37 |
| | do | 14.50 | 15.50 | 15.25 | 14.37 | − .13 |
| | Lot IV | 16.75 | 17.69 | 17.50 | 16.50 | − .25 |
| | do | 15.81 | 16.50 | 16.37 | 15.25 | − .56 |
| Shoulders[1] | Lot I | 15.00 | 16.81 | 16.62 | 15.44 | + .44 |
| | do | 15.50 | 17.56 | 17.25 | 16.06 | + .56 |
| | Lot III | 13.44 | 14.94 | 14.75 | 13.62 | + .18 |
| | do | 12.62 | 14.25 | 13.94 | 12.87 | + .25 |
| | Lot IV | 13.69 | 15.50 | 15.25 | 14.06 | + .37 |
| | do | 14.56 | 16.25 | 16.00 | 14.87 | + .31 |
| Bacon sides | Lot I | 6.00 | 7.44 | 7.25 | 6.56 | + .56 |
| | do | 5.81 | 7.25 | 7.12 | 6.44 | + .63 |
| | Lot II | 4.50 | 5.94 | 5.69 | 5.00 | + .50 |
| | do | 3.62 | 4.62 | 4.37 | 3.87 | + .25 |
| | Lot III | 5.50 | 6.69 | 6.50 | 5.75 | + .25 |
| | do | 5.06 | 6.37 | 6.19 | 5.56 | + .50 |
| | Lot IV | 4.94 | 6.19 | 6.00 | 5.37 | + .43 |
| | do | 5.44 | 6.81 | 6.56 | 5.94 | + .50 |

[1] Owing to an accident the shoulders of Lot II were not cured.

TABLE V.—*Summary of curing and smoking.*

| Process. | Hams. | | Shoulders. | | Bacon sides. | |
|---|---|---|---|---|---|---|
| | *Pounds.* | *Per cent.* | *Pounds.* | *Per cent.* | *Pounds.* | *Per cent.* |
| Total green weight | 121.81 | 100.00 | 84.81 | 100.00 | 40.87 | 100.00 |
| Weight after curing | 129.69 | 106.05 | 95.31 | 112.38 | 51.31 | 125.53 |
| Weight after draining | 128.25 | 105.27 | 93.81 | 110.61 | 49.69 | 121.56 |
| Weight after smoking | 119.81 | 98.36 | 86.94 | 102.50 | 44.50 | 108.86 |
| Gain by curing | 6.44 | 5.27 | 9.00 | 10.61 | 8.82 | 21.56 |
| Loss by smoking | 8.44 | 6.91 | 6.87 | 8.11 | 5.19 | 12.70 |
| Net gain (+) or loss (−) | −2.00 | −1.64 | +2.13 | +2.50 | +3.63 | +8.86 |

It is seen from this table that there was no marked difference in the shrinkage of the cuts from the different lots. The large gains in weight in the shoulders and bacon sides were partly due to the fact that they remained in the brine for 8 weeks and absorbed more moisture than the hams.

The color of the smoked meat was very uniform, showing a rich brown on the outside. When cut the hams and shoulders had a rich color, not the shade of blood, but not in any way bleached out. The color was very uniform among the several lots.

Sample slices from all of the cuts from each hog were compared and no difference could be noticed in flavor, palatability, or cooking qualities. It was impossible to differentiate between the cured meat from the various lots; it was all excellent in quality, with an appetizing odor, and a delicate flavor.

## SUMMARY OF CARCASS DATA.

From a careful review of the foregoing the following conclusions are drawn:

Dried pressed potato meal fed with any of the three supplements used in the experimental feeding produced pork equal in quality to that produced by a ration of corn meal and tankage.

Dried pressed potato meal supplemented with old-process linseed-oil meal (Lot III) produced a carcass which for degree of finish excelled even that of the corn-meal hog (Lot I), and the degree of finish on the other two lots was but little inferior to that on the check hog (Lot I).

No difference could be noticed in any way in the curing qualities or in the excellence of the finished product raised from the hams, shoulders, and bacon sides of the hogs fed in the four different lots.

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UNITED STATES DEPARTMENT OF AGRICULTURE
**BULLETIN No. 597**
Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER. April 9, 1918

# SOME BIOLOGICAL AND CONTROL STUDIES OF GASTROPHILUS HAEMORRHOIDALIS AND OTHER BOTS OF HORSES.[1]

By W. E. Dove, *Scientific Assistant, Insects Affecting Domestic Animals.*

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## INTRODUCTION.

In compliance with requests from farmers and horse breeders of the Dakotas and Montana regarding "fly annoyance" to horses, a survey of conditions was made in the autumn of 1914 by Mr. F. C. Bishopp. Under the direction of Dr. W. D. Hunter and the supervision of Mr. Bishopp, investigations were undertaken in the following summer upon the European *Gastrophilus haemorrhoidalis*, commonly known in that section as the "nose-fly."

The preliminary investigations in the summer of 1915 revealed the fact that the concentration of horses in pastures had rendered breeding conditions practically ideal for bot-flies, and that a most serious fly nuisance had developed which implicated three species of Gastrophilus. This concentration of horses in pastures may be attributed in part to the advent of gas engines, automobiles, and tractors, and to maximum prices, which has encouraged the breeder to meet the great demand for army horses. Within the nose-fly district is to be found one of the largest horse-sale points in the world.

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[1] Mr. H. B. Bradford made the drawing illustrating the eggs of Gastrophilus, and Mr. W. N. Dovener made those illustrating the larvæ and dorsal aspects of the adults. Many of the photographs were made by Mr. A. K. Pettit.

## BRIEF LIFE HISTORY OF GASTROPHILUS.

Our knowledge of the life histories and habits of these insect pests, which is always essential to successful control, is confined for the most part to the classical accounts of Bracy Clark in 1797 and subsequently, although later writers have added important details.

When the female of *Gastrophilus intestinalis* (*G. equi*) becomes sexually mature it is most often observed hovering near the inside of the knee of a horse, where by preference the eggs are deposited. After a few days, when the larvæ develop within the eggs, the horse by scratching the forelegs with the teeth provides sufficient moisture and friction to remove the operculum or small cap of the eggs and inadvertently the larvæ are taken within the mouth. The empty eggshells remain attached to the hairs of the legs, whereas the larvæ are carried with the food or water to the stomach, where attachment to the stomach walls takes place. Here they undergo development during the autumn, winter, and spring months, and later are passed from the horse with the manure. At this stage pupation ensues and adult flies are produced.

The other species of bots also spend similar larval periods in the animal, but have habits peculiar to the particular species.

## HISTORICAL.

The literature containing historical references to the Oestridae carries one to a most remote time. The ancient Greeks and the Latins refer to "an unspeakable fright of cattle," though later writers are not agreed as to whether it was produced by an oestrid or a tabanid. It is certain, however, that Aristotle knew the forms found in the throats of deer.

The Greek veterinarians Theomnestus and Absyrtus give us the earliest record which could be referred to Gastrophilus when they write of the "biting worms which fix themselves to the anus of the horse." In order to destroy them it was recommended that they be torn from the anus with the fingers and covered with hot ashes and pulverized salt.

Malpighi in 1697 gave the first description of a gastrophilid larva taken from the stomach of an ass. According to Joly, it belonged to the species *G. intestinalis* De Geer, while to Brauer it was *G. flavipes* Olivier. Gaspari published an erroneous opinion that *G. haemorrhoidalis* deposited its eggs in the rectum of the horse during defecation, and that the larvæ migrated to the stomach until about fully developed. Vallisnieri and Réaumur made the same erroneous diagnosis.

Linnaeus, Fabricius, and De Geer occupied themselves with the early classification, and not until 1797, with Bracy Clark, does the natural history of the Oestridæ truly commence. To this historical work of Bracy Clark a few additions, many of which are cited in the bibliography, have been made by subsequent writers.

In conformity with the rules of nomenclature and following the reestablishment of the Linnaean designation "*intestinalis*" by Guyot, "*Gastrophilus intestinalis*" is given preference rather than "*Gastrophilus equi.*"

Aside from priority, the specific name "*equi*" is not reliable, since there are several species of Gastrophilus which infest the horse; moreover "*intestinalis*" has been adopted by a number of dependable authorities.

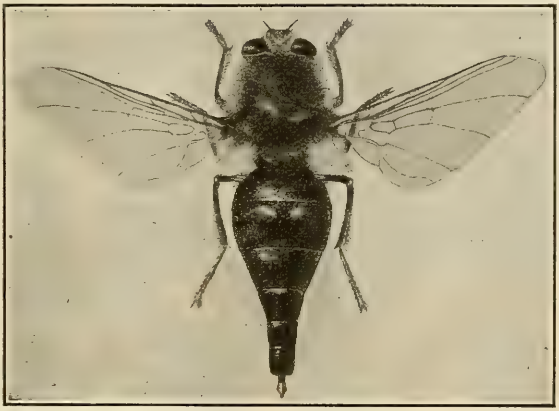


Fig. 1.—*Gastrophilus nasalis:* Female. Oviposits commonly under the jaws of horses. Greatly enlarged. (Original.)

## SPECIES DIFFERENTIATION.

The eggs, larvæ, and adults are so easily distinguishable in this genus that it does not require a study of detailed descriptions to enable a student to determine the species. (Figs. 1, 2, 3.) Prof. Garman's key to the wing venation, a reliable index to the species, is here quoted.

Key to Wing Venation of Gastrophilus Spp.

| | | |
|---|---|---|
| 1. | Discoidal cell not closed by a cross vein | *G. pecorum.* |
| | Discoidal cell closed by a cross vein | 2 |
| 2. | Wings marked with brown | *G. intestinalis.* |
| | Wings not marked with brown | 3 |
| 3. | Anterior basal cell nearly or quite equal to the discoidal cell in length | *G. nasalis.* |
| | Anterior basal cell markedly shorter than the discoidal cell | *G. haemorrhoidalis.* |

The cloudy wings of *G. intestinalis* and its habit of depositing upon any convenient portion of the horse where it is not disturbed, but most commonly on the forelegs, will enable one to distinguish it most readily.

*G. nasalis* is smaller than *G. intestinalis*, densely hairy, with the thorax yellowish red or rust colored. Its most common place of oviposition is under the jaws, but it is sometimes observed to oviposit upon the flanks or forelegs of the animal. Unlike *G. intestinalis*, it does not remain near the animal prior to the deposition of a second egg.

*G. haemorrhoidalis* is easily distinguished by the bright orange red on the tip of the abdomen. The thorax above is olive gray and hairy, with a black band behind the suture. The base of the abdomen is whitish and the middle blackish, which is in strange contrast with the orange red of the end. It deposits only upon the small hairs on the lips of horses and mules.

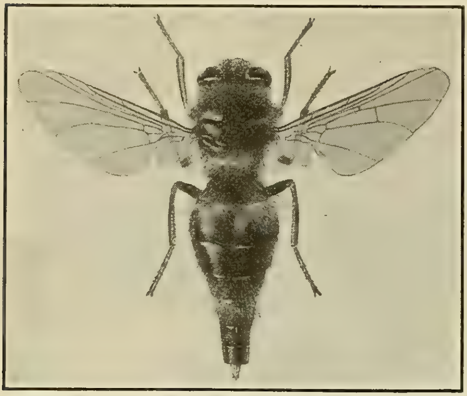


FIG. 2.—*Gastrophilus haemorrhoidalis:* Female. Oviposits only upon the small hair on the lips of horses, preferably the portions moistened by saliva. Greatly enlarged. (Original.)

The males of *G. intestinalis* and *G. haemorrhoidalis* are often found awaiting the approach of females to the horses, and when they arrive the flies copulate.

The species characteristics of the eggs of the three species occurring in the United States can best be observed by referring to the illustration (fig. 3). While *G. intestinalis* is usually attached about one-half its length to the hair, *G. nasalis* is attached almost its entire length. *G. haemorrhoidalis* is always found attached to the base of a hair on the lips. These hairs are so small that one does not observe them with the naked eye. It is the only Gastrophilus depositing here. The egg is black in color and the stalk is partially inserted in the pore of the skin at the root of the hair.

Fourth-stage lavæ, as can be seen in the illustration (Pl. I), vary in size when fully developed. In all specimens the eleventh ring is completely deprived of spines, but upon the other rings the variations are often misleading. However, the key given herein will assist in identifying fully developed larvæ.

### KEY FOR THE IDENTIFICATION OF FULLY DEVELOPED LARVÆ OF GASTROPHILUS SPP.

1. Spines arranged in two alternating rows, the first more developed than the second ---------- 2
   Spines in one row ---------- *G. nasalis.*
2. Spines long and prominent, lacking only two to three pairs on dorsal center of the ninth row ---------- *G. intestinalis.*
   Spines short and segments prominent. Completely deprived or possessing only two to three pairs of spines on either side of the dorsal center of the ninth ring ---------- *G. haemorrhoidalis.*

## DISTRIBUTION IN THE UNITED STATES AND PROBABLE DISPERSION.

Recently Mr. F. C. Bishopp, in communication with a large number of horse breeders, has determined some facts on the distribution and other points, especially in regions adjoining the district where *G. haemorrhoidalis* is known to occur. This information will be published later. It will suffice to say here that *G. haemorrhoidalis* occurs in sufficient numbers to warrant the adoption of control measures in the Dakotas, Montana, and northern Wyoming. According to Dr. C. Gordon Hewitt, Dominion Entomologist, the species extends over a considerable area in the Dominion of Canada. Two of the species, *G. intestinalis* and *G. nasalis*, are found throughout the United States where horses are present. *G. pecorum* is not known to occur in the United States.

The constant migration of the larvæ of *G. haemorrhoidalis* to the region of the anus and their dropping, which occurs over a long period, indicates that the principal means of dispersion is through the movement of infested horses. During the past few years large numbers of horses, which have been purchased in the infested district for European army purposes, were concentrated at certain points until more could be assembled for shipment. This occurred at times when larvæ were normally dropping and allowed ample time for this species to become established. Although the adults may not have appeared in sufficient numbers to attract attention in new districts, this will undoubtedly occur in the near future.

The comparatively short duration of adult life and the functions of the adults restricted to depositing eggs indicate that little dispersion takes place by actual flight. In the nose-fly district there has been a slow but gradual spread of the species each year, as verified by hundreds of statements from farmers and horse breeders.

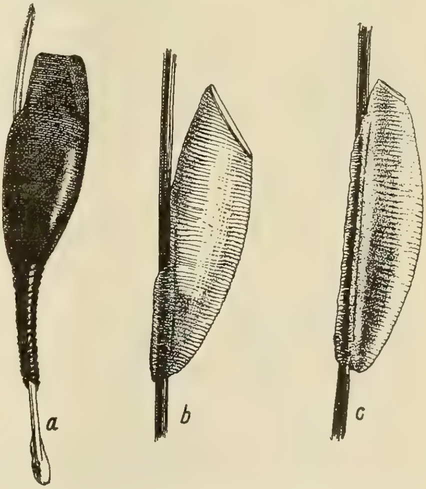


Fig. 3.—Gastrophilus eggs attached to hairs: *a*, *G. haemorrhoidalis* and hair removed with root; *b*, *G. intestinalis*; *c*, *G. nasalis*. Greatly enlarged. (Original.)

## LARVAL COLLECTIONS AND REARING TECHNIQUE.

An insectary was located in Aberdeen, S. Dak., where all types of farm and city operations concerned with the use of horses could be observed, and at the same time easily accessible to a rendering plant where post-mortem examinations could be made. Horses in pasture were available in all directions, and livery barns were located within a mile and could be conveniently visited.

Horses of many types, representing every locality in the immediate vicinity, could be observed in the livery barns, and it was from these horses that breeding material of *G. haemorrhoidalis* was obtained. While examinations of droppings were made, most of the larvæ utilized were removed from their places of attachment about the anus. These were sufficiently developed to pupate and produce adults, and did so even though they were not handled carefully with the forceps in removal. The number of horses in the liveries varied, but usually from 30 to 100 were observed daily. In order to obtain an ample supply of larvæ additional collections were made when near-by farmers came in with teams.

In rearing adults, the larvæ were placed in tin boxes upon moist sand in California parasite-rearing boxes, or in bread trays upon grass sod. These were usually kept in cages 18 by 18 by 18 inches, each of which was fitted with a door of sufficient size to permit the removal of trays for examination. When adults emerged it was necessary to confine them in tightly fitted cages which excluded sunlight, and to keep them supplied with grass sod or green foliage to lessen activity. Sunlight has an unusually great attraction for adult flies. They are very active and will damage their wings against the screen or crawl into a cage crevice and die. More especially has this been noted with *G. haemorrhoidalis*.

## LARVAL INFESTATION AND INJURIES.

### REVIEW OF OPINIONS.

In reviewing opinions on the economic importance of bot-flies, one naturally encounters the ideas of Bracy Clark, which have been passed from one to another since 1798. He believed that larvæ by irritating the membranes of the stomach and intestines often relieved a general disorder of the system, but mentions that, however useful a few of these natural stimuli may be, they result in large infestations which should at all times be prevented. He indicates in this paper that the infestations coming under his observation did not greatly exceed 100 larvæ, and for the most part not more than a half dozen were to be found.

We find the following statement by R. S. MacDougal (1899):

> Opinion differs a good deal as to the harmfulness of these bots. In conversations with veterinary surgeons I find there is a tendency to minimize the evils that may attend bot presence. There are authenticated records, however, which place the possibility of grievous harm beyond all doubt. Inflammation, ulcers, interference with digestion, interference with the free passage of food or exit of waste matters, loss of appetite and condition, have been frequently

Warburton (1899) says:

> The irritation they set up can not fail, however, to be detrimental to the horse's health even where no ill effects are obvious. The fact seems to be that a horse in good condition and well fed can endure the presence of numerous bots in the stomach without great inconvenience, but if the animal is in poor condition gastric enteritis, perforation of the stomach, and death may result.

In Miss Ormerod's report of 1890, Dr. Hy. Thompson, of Aspatria, Cumberland, England, says:

> I have never seen the stomach entirely perforated, but the irritation induced by the development of the larva causes in many cases a great wasting of flesh in the horse.

Perroncito (1902) describes lesions caused by Gastrophilus larvæ, some of which resulted in perforation of the stomach walls and death of the animals. Cases of Flohill, Numan, Conti, and others, as well as cases coming under his personal observation, are mentioned.

Kröning (1906) reports having observed cachexia accompanied with colic in young colts during the previous five years, and attributes this to infestations of bots.

Lahille (1911) makes mention of larvæ causing death of animals and cites the possibility of infection in the lesions.

Velu (1913) reports that a drought greatly favored attacks in Morocco and more than 1,000 larvæ were usually found in post-mortem examinations. All three of the more common species were present, but *G. nasalis* caused lesions which resulted in death of the animals.

The universal distribution of *G. equi* and *G. nasalis* has familiarized persons in every locality to some extent with bots of horses, yet their opinions are naturally varied as to the economic importance of the larvæ. There are some who believe that there are no ill effects; others think that they are beneficial; while some even believe that a horse will die if the bots are removed. Such conceptions are most prevalent among "horse doctors" who are not in possession of an effective treatment for the removal of bots. On the other hand, it is a difficult matter to convince a horse breeder that bots are beneficial when his yearling colts kept in pastures have a rough coat, fail to grow or fatten, show no symptoms of disease, and at the same time possess a good appetite. Many breeders have made post-mortem examinations of horses for their personal satisfaction. The finding of hundreds of well developed larvæ with conspicuous lesions conveys vivid impressions and greatly emphasizes the importance of bots. Others, without a knowledge of the development of bots within the horse, often make examinations after numbers have been passed and the lesions healed; or when the larvæ are small and probably not observed by an untrained eye they are regarded as less detrimental. It is only by careful post-mortem examinations of large numbers of horses that conclusions can be drawn, and these may be erroneous if one is not familiar with the various species, their usual points of attachment, and phenomena peculiar to each.

## SPECIES IMPLICATED.

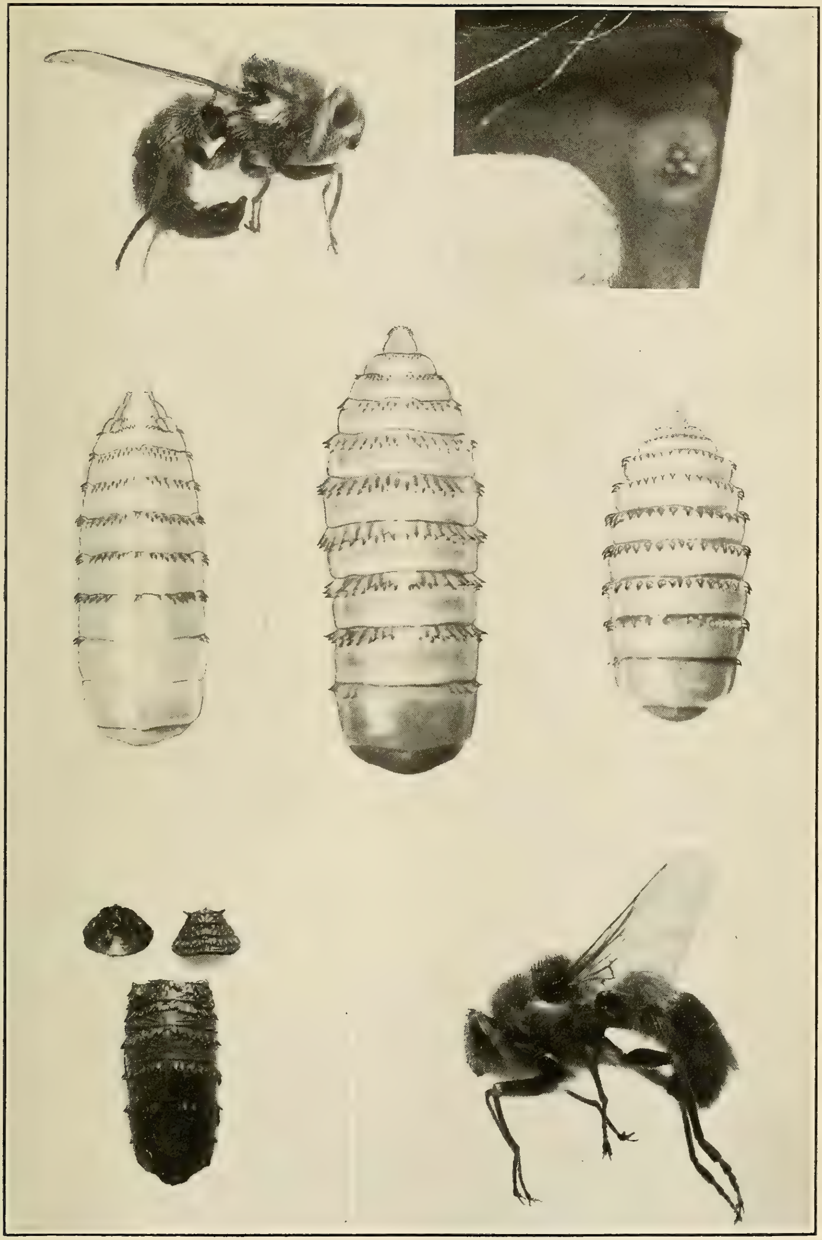
*Gastrophilis intestinalis*, "the common bot," attaches ordinarily in the stomach, has been taken in the duodenum, but has never been found permanently attached in any other regions (Table I, p. 10). Rarely it may become temporarily attached in the rectum, but is not present with an alveolus or lesion.

*G. nasalis*, "the throat bot," attaches by preference in the duodenum, is often found in the stomach, and is the only known species which attaches in the pharynx. Due to the attachment in the throat, it not only becomes a species of vital importance when the bots congregate in sufficient numbers to hinder or cut off the breathing of the horse or cause an infection, but in this location they can not be removed by an internal treatment. In the duodenum the infestation may be sufficient to hinder or stop the passing of excreta. Table I (p. 10) shows the comparative abundance in the stomach and duodenum during the period that larvæ are well developed and naturally drop from the host.

Various cases are on record in which this species has been removed from the pharynx, in all of which the authors considered it a serious detriment to the horse. While larvæ which were not sufficiently developed to be determined with authenticity have frequently been removed from the pharynx, 8 larvæ of *G. nasalis* were collected in the throat of a dray horse by J. L. Webb at Reno, Nev., on August 29, 1916. In numerous cases, both at Aberdeen, S. Dak., and at Dallas, Tex., the author has found lesions present in the pharynx, indicating that the larvæ had become fully developed and had passed out of the horse. In making post-mortem examination of horses to determine the attachment of young larvæ in the pharynx extreme care should be exercised, as young meat-infesting larvæ may be confused with Gastrophilus. Upon hatching they migrate from the light into the nostrils and may be found in the pharynx and other locations in the throat.

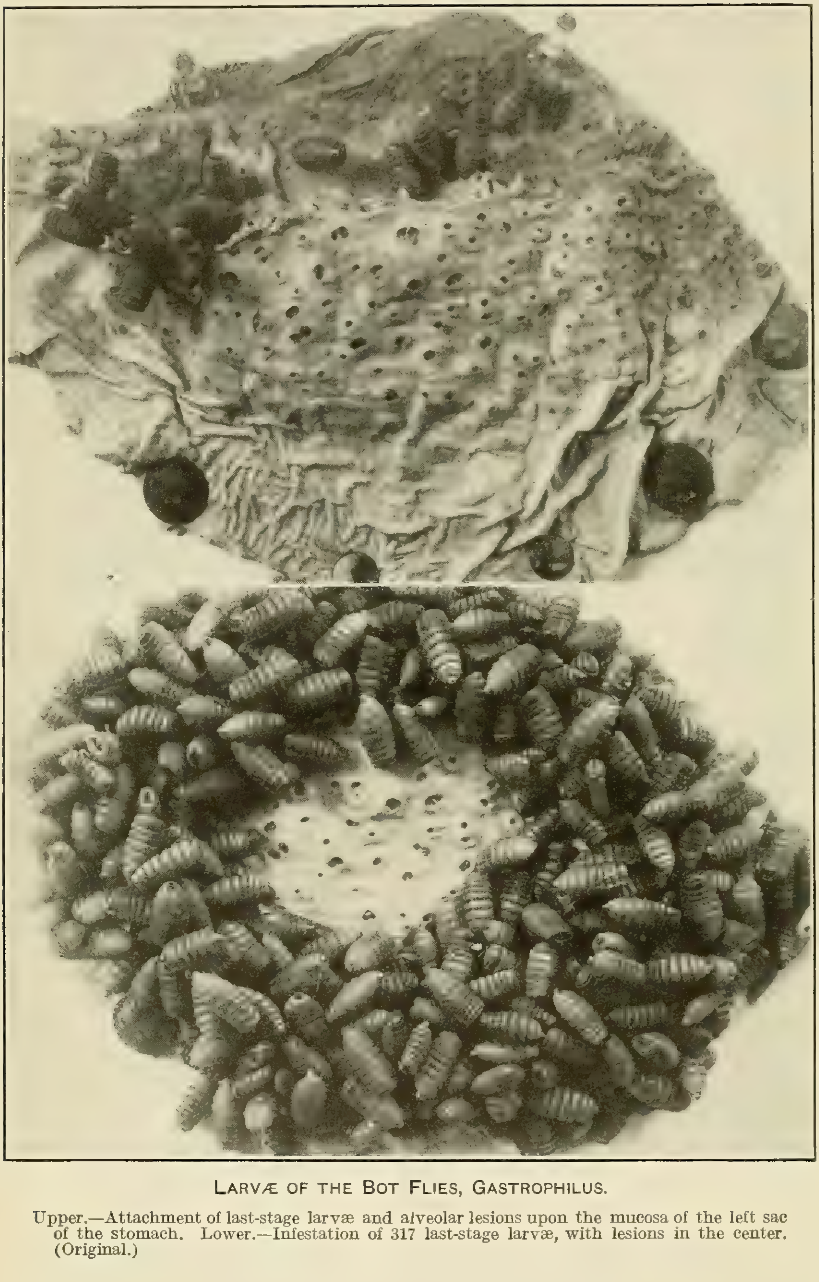
Dr. Buffington (1905), of Brooklyn, Iowa, gives a valuable history of a case in which a mare died as the result of an infestation of *G. nasalis* in the pharynx. This animal had experienced difficulty in eating for more than a month, and was unable to take food for a week prior to November 26, 1903. At this time she would drink water, but after masticating food a very little, would drop it out. The symptoms were those of paralysis of the muscles of deglutition and there was a very offensive odor about the head. Four days later, when the animal died, the nasal, pharyngeal, laryngeal, and upper portion of the œsophageal mucous membranes were found to be gan-

PLATE I.



STAGES OF THE BOT FLIES, GASTROPHILUS.

Upper left.—*Gastrophilus haemorrhoidalis:* Female, side view. Upper right.—*G. haemorrhoidalis.* Larvæ attached to margin of anus of horse. Left of center.—*G. haemorrhoidalis:* Last-stage larva. Center.—*G. intestinalis:* Last-stage larva. Right of center.—*G. nasalis:* Last-stage larva. Lower left.—*G. intestinalis:* Puparium, showing cap split off by fly in emergence. Lower right.—*G. haemorrhoidalis:* Male, side view. (Original.)



LARVÆ OF THE BOT FLIES, GASTROPHILUS.

Upper.—Attachment of last-stage larvæ and alveolar lesions upon the mucosa of the left sac of the stomach. Lower.—Infestation of 317 last-stage larvæ, with lesions in the center. (Original.)

grenous and the source of the offensive odor. From the pharyngeal walls 12 or 15 larvæ were removed, 6 of which the present author obtained. Three of these larvæ were determined as *G. nasalis*, and it is reasonable to believe that the other larvæ, which were not sufficiently developed for identification, were of the same species.

The larvæ of *G. haemorrhoidalis*, "the nose-fly," as is shown in Table I, may be found in the stomach, duodenum, or rectum, and also attached about the margin of the anus, where they change in color from pink to a greenish, become accustomed to the atmosphere, and later drop to the soil for pupation. During the early stages they attach within the stomach and duodenum, but later loosen themselves and reattach in the rectum, from which they gradually move to the anus. The attachment of clusters of these larvæ in the rectum has been known to stop the passage of excreta and to cause abnormal protrusions accompanied by much suffering.

About June 1, 1915, a horse breeder in Montana experienced a case of obstruction of the rectum in a yearling colt. On three different occasions within one week the animal was observed lying down in the pasture with the rectum greatly protruded. Each time it was washed with warm water and replaced, but the larvæ causing it were not observed until the third time. The exact number of bots removed by hand was not ascertained, but upon their removal and replacement of the rectum the animal gradually recovered.

Table I records a maximum of 1,032 bots removed from a 2-year-old colt. The infestation consisted of 695 *G. intestinalis*, 248 *G. nasalis*, and 89 *G. haemorrhoidalis*. This was the greatest number obtained during any of the autopsies. Colts are always the most heavily infested, especially when they come from summer pastures, and in this case the animal was greatly emaciated, possessed a dull coat, and, in spite of a good appetite and an abundance of food during the previous winter, failed to grow or fatten. It had suffered from a broken shoulder, the result of a kick, which ordinarily would have healed promptly at this age, but instead it remained for months a cripple. The owner, believing that it would never thrive, caused the animal to be killed, and the post-mortem examination revealed no abnormal condition, except the bot infestation and the broken shoulder. It appeared that so much vitality was sapped through the inroads of bot infestation that the colt had no recuperative surplus.

At the date of the post-mortem examination 89 *G. haemorrhoidalis* larvæ had migrated to the rectum and attached. They were not sufficiently developed to pass out and were attached at this point with lesions characteristic of those usually found in the stomach.

In Table I many of the infestations noted were comparatively small when the post-mortem examination was made, and attention should be called to the fact that all of these examinations were made during the time when larvæ were naturally dropping with excreta. The numbers do not show the maximum infestations of larvæ that may have been present. Many of the dead horses examined had been subjected to various environments prior to the autopsies and are not representative of infestations found when horses have spent the entire previous summer in pastures.

TABLE I.—*Gastrophilus findings in post-mortem examinations of horses at Aberdeen, S. Dak., 1915–16.*

| Horse died. | Spent summer. | Larvæ in stomach. | | | | Larvæ in duodenum. | | | | Larvæ in rectum, G. haemorrhoidalis. | Total number larvæ. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | G. intestinalis. | G. nasalis. | G. haemorrhoidalis. | Gastrophilus sp. small. | G. intestinalis. | G. nasalis. | G. haemorrhoidalis. | Gastrophilus sp. small. | | |
| 1915. | | | | | | | | | | | |
| June 7 | | 295 | 11 | 21 | | | | | | 9 | [1] 337 |
| July 8 | | 158 | | 12 | | | | | | 14 | 184 |
| July 14 | | 103 | | 1 | | 11 | 1 | | | | 116 |
| July 21 | | 58 | 290 | 3 | | | | | | | 351 |
| July 26 | Driven on streets | 33 | | | | | | | | 1 | 34 |
| Aug. 12 | do | 18 | | | | | | | | | 18 |
| Aug. 23 | do | 6 | | | 10 | | | | | | 16 |
| Aug. 23 | In pasture, 1915 | | | | 67 | | | | | | 67 |
| Aug. 26 | | 9 | 1 | | 35 | | | | | | 45 |
| Aug. 26 | In pasture, 1915 | 5 | | | 71 | | | | | | 76 |
| Aug. 26 | | | | | 42 | | | | | | 42 |
| Sept. 13 | Country and town driving | | | | 217 | | | | | | 217 |
| Sept. 17 | | | | | 101 | | | | 71 | | 172 |
| Sept. 20 | Driven on streets | | | | | | | | 22 | | 22 |
| Sept. 21 | do | 1 | | | 4 | | | | 13 | | 18 |
| Oct. 1 | Farm work | 6 | | | 50 | | | | 82 | | 138 |
| 1916. | | | | | | | | | | | |
| May 20 | do | 123 | 15 | 7 | | | | | | | 145 |
| May 20 | | 7 | | | | | | | | | 7 |
| May 29 | | 56 | 1 | 10 | | | | | | | 67 |
| May 29 | | 44 | 10 | 35 | | | 22 | | | | 111 |
| June 7 | | 64 | | | | | 5 | 2 | | | 71 |
| June 8 | | 18 | | 5 | | | 19 | | | | 42 |
| June 16 | | 16 | | 1 | | | | | | | 17 |
| June 21 | Driven on streets | 3 | | | | | | | | | 3 |
| June 26 | In pasture, 1915 | 687 | 70 | | | 7 | 178 | | | 89 | [2] 1,032 |
| June 28 | do | 72 | 2 | 26 | | | 137 | | | | 237 |
| July 11 | Farm work | 116 | 2 | | | | 19 | 1 | | | 138 |
| July 17 | do | 92 | 5 | | | | 144 | | | | 241 |
| July 24 | In pasture | 461 | | | | | 149 | | | | 610 |
| Aug. 3 | Farm work | 151 | 1 | 1 | | | | | | | 153 |
| Aug. 4 | | 39 | 16 | 4 | | 4 | 30 | | | | 93 |
| Aug. 7 | | 20 | | | | | 25 | 2 | | | 47 |
| Aug. 6 | | | | | 13 | | 1 | | | | 14 |
| Aug. 11 | | 24 | | | | | | | | | 24 |
| Aug. 11 | | 29 | 14 | 1 | | | 4 | | | | 48 |
| Aug. 23 | | 1 | | | 6 | | | | 26 | | 33 |
| Aug. 23 | | 44 | | 8 | 8 | | 26 | | 16 | | 102 |
| Aug. 26 | | 23 | | | | | 1 | | 12 | | 36 |
| Sept. 1 | | 1 | | | 20 | | | | | | 21 |
| Sept. 8 | | 2 | | 1 | 1 | | | | 14 | | 18 |
| Sept. 11 | | 5 | | | | 1 | | | | | 6 |
| Sept. 16 | | 2 | | | 37 | | | | 31 | | 70 |

[1] Includes 1 *G. intestinalis* temporarily attached in colon.
[2] Includes 1 *G. intestinalis* temporarily attached in rectum.

## LARVAL MOVEMENTS WITHIN THE HORSE.

When a post-mortem examination is made, the larvæ usually are found quiescent, although occasionally some may be observed to move the posterior end slightly. The smaller larvæ show more activity than do well-developed ones.

Other than *G. nasalis*, which sometimes attaches in the pharynx, the first-stage larvæ attach to various portions of the stomach and duodenum. In the stomach young larvæ have been removed from various locations, including both the cardiac and pyloric portions. The last-stage larvæ of all three species are found in the various portions. *Gastrophilus intestinalis* is confined for the most part to the mucosa of the left sac, though this species has been taken in the right sac and in the duodenum (see Table I). In the early stages some of the larvæ either change places of attachment or pass out of the horse undeveloped. With last-stage larvæ the indications are that, excepting *G. haemorrhoidalis*, they remain attached at one place continuously during feeding, as in early spring the number of larvæ and lesions upon the mucosa is the same.

During the early spring or perhaps even in winter the larvæ of *G. haemorrhoidalis* move from the stomach and duodenum to the rectum where they may be found permanently attached in clusters. It is evident that they feed in this position, as lesions are sometimes present. Later when they move to the margin of the anus no lesions are present and apparently the larvæ only pause to become accustomed to air temperatures before dropping.

There is no definitely periodic larval migration of *G. haemorrhoidalis*, as some last-stage larvæ are found in the stomach and duodenum until early fall. Through the courtesy of Dr. L. Van Es, of the North Dakota Experiment Station, some post-mortem examinations were made at Fargo, N. Dak., and larvæ preserved according to their location within the animal. During the winter these larvæ were found in the stomach, and on July 10, 1916, 3 larvæ; July 14, 1916, 16 larvæ; and August 18, 1916, 2 larvæ were fully developed and in the same regions. This coincides with the findings at Aberdeen, S. Dak., although one last-stage larva was found in the stomach on September 8, 1916.

### POINTS OF LARVAL ATTACHMENT.

When an opened stomach of a horse is examined, one is impressed by the contrast in the left and right portions. Around the entire organ a line of demarcation is represented by a prominent sinuous crest. In the left portion, which is often called the left sac, the mucosa is white, dry, resistant, and covered by a thick layer of epithelium. This covering is identical with that of the esophagus and may be considered as a widening of the esophageal canal.

Dr. Guyot, in describing the mucosa of the left sac, says the structure is analogous to that of the skin. It is dermo-papillary, with epithelium of the Malpighian type, but possesses a muscle, the *muscularis mucosae*, which is peculiar to it. The structure of the right sac differs in having a soft membrane with an epithelium formed by a single layer of cells.

*G. intestinalis* larvæ are practically always found attached in the left sac, and it is the opinion of Dr. Guyot that this portion affords the most stable point for larval attachment. He thinks that cases are exceptional in which larvæ maintain themselves in the right sac. This, however, does not explain the attachment of *G. nasalis* in the duodenum and to the walls of the pharynx, nor does it account for the attachment of *G. haemorrhoidalis* in the right sac of the stomach, in the duodenum, or in the rectum. As has been mentioned by Dr. Guyot, the reason for attachment in certain regions of the digestive tract will remain a mystery until the manner in which larvæ are nourished is ascertained.

Various investigators have been unable to discover white or red corpuscles of the horse in the pharynx and other alimentary portions of the larvæ. Clark believed their food was probably the chyle, but Guyot rejects this explanation, as larvæ in the pharynx are located where this could not possibly be utilized. As *Oestrus ovis* larvæ nourish themselves with the mucus secreted by the mucosa of the nose and frontal sinuses of sheep, and as those of Hypoderma utilize the pus of the abscesses which they create by their presence in cattle, he believes it permissible to suppose that those of Gastrophilus find nutriment in the inflammatory products of the gastric mucosa.

It would appear, from observations, that Gastrophilus larvæ sometimes feed upon the blood of the animal, although they are not dependent upon it for subsistence. The red and maroon color of *G. intestinalis* and *G. hœmorrhoidalis*, with their attachment upon points other than the mucosa of the left sac, would bear out this hypothesis, which is further supported by the fact that *G. haemorrhoidalis* when fully developed in the rectum still retains a pinkish color.

## THE ALVEOLAR LESIONS OF THE STOMACH.

In Dr. Guyot's examinations of lesions caused by the attachment of larvæ to the mucosa of the left sac, the muscular coat was not damaged. The condition found was merely a localized inflammation around the point of larval attachment, in which the derma had been invaded by leucocytes. He assumes that this is only the common inflammatory reaction which would be normally produced around any foreign body.

In following these studies Perroncito found that the bottom of the alveolus varied in size and became the seat of a more or less remarkable inflammatory process. This produced a thickening of the walls of the stomach and finally the disappearance of the muscular tissue, which becomes hard and compact, preventing the normal functions of the stomach. He mentions cases of perforations, lacerations, and ruptures of the stomach observed by Flohill, Numan, Conti, and Brusasco, and calls attention to alveolar lesions which are naturally more predisposed to induce various infective diseases. (See Plate II.)

### GASTROPHILUS AND SWAMP FEVER.

Aside from the lesions which may induce the entrance of organisms of infectious diseases, the Seyderhelms, of Strassburg (1914), report results which they think implicate Gastrophilus larvæ in the causation of swamp fever. It is believed by them that the larvæ excrete a specific toxin which is the cause of the disease, for by administering extracts of these larvæ symptoms typical of swamp fever have been observed. The coincidental distribution of Gastrophilus with that of this disease would appear to bear out the hypothesis. It is said that the most virulent reactions were obtained in these experiments with *G. haemorrhoidalis* larvæ.

### BOT-FLY ANNOYANCE.

In those portions of the country where the nose-fly does not occur, horses are seldom sufficiently annoyed to require protection. The persistence of the common bot-fly and the repeated stamping of the animals are evidence that it is annoying, but when the throat bot-fly "strikes" the action of the horse becomes more violent.

The throat bot-fly is less persistent but more determined in depositing, and the horse usually responds with a violent nod or jerk, the violence depending upon the nervousness of the individual. In plowing it is sometimes necessary to place a strip of cloth or a small branch of a tree underneath the throat latch and extending to the bit rings.

In the nose-fly section the annoyance is produced by the two generally distributed species in addition to *G. haemorrhoidalis.* Upon the approach of this fly the horse moves the head backward and forward to prevent its darting on the lips, but this only seems to arouse its determination, for it quickly alights on the lips and within a second or two deposits a black egg. It apparently occasions a most annoying sensation, and a horse will most often snort and rub violently against the ground, a bowlder, a tree, barb-wire fence, or any convenient object.

The effects of ovipositions on pastured animals are worry, loss of flesh, and mechanical injuries. If the lips are examined barb-wire lesions will be found which resulted from the rubbing of the horse following an oviposition. (See Plate IV.)

With an unprotected work animal one may be suddenly confronted with a jerk or a similar violent action of the animal at each oviposition of the fly. When a few eggs have been deposited the animal proceeds from infuriated shaking of the head, sometimes accompanied by loud snorts, to complete loss of self-control, and will use any means for self-protection. Numerous runaways naturally occur and serious accidents have also occurred when horses were being used for mowing. The majority of farmers and breeders contend that "the fly stings the horse in the nose." The reactions of the animals are often so violent that at first it seemed that the horses really experienced pain. Dr. Parker, of the Montana State Board of Entomology, has published some notes[1] to the effect that the eggs were thrust into the skin, but he failed to recognize the minute hairs to which the eggs are attached. The pointed portion of the egg is merely a device by which it is attached to the hair. A horse does not experience any pain, as the ovipositions do not puncture the skin. Neither do the flies deposit in the nostrils. Careful search has failed to disclose a single egg in such locations, and it would appear that the snorting of the animal has given rise to this "popular opinion." It is believed, however, that annoyance is largely due at first to an instinctive fear and later to a tickling sensation when the eggs are attached to the minute hairs, as the lips are the most sensitive portions of the horse. Practically all horses in this section have sore lips from eating a "wild barley" or "foxtail grass" (*Hordeum jubatum*) and there is no doubt that this soreness contributes to the annoyance.

## NATURAL PROTECTION OF HORSES.

The flies show no preference as to type, breed, color, or age, but naturally oviposit upon unprotected animals. Horses seek protection in pastures, the individuals gathering in a bunch and resting their lips upon one another. Colts and young animals not high enough to protect their lips in this way receive an abundance of eggs.

A horse will sometimes hold the lips upon the ground as if grazing, upon detecting the presence of the fly, and when held in such position the adult fly is rarely observed to oviposit. Often the annoyance of biting flies and other depositing Gastrophilus will cause a horse to walk, holding the lips near the ground. Frequently other horses will follow and protect themselves by placing their lips upon his back or the backs of other animals in the line. Usually they search for the highest elevation where the breeze is blowing, or for standing water, but if an open stall is convenient they will use it to good advantage. If protection is not found an unconfined animal will often wander a great distance from home.

Upon a bright still day ovipositions occur from 8 a. m. until about sunset, and the group of horses may be observed to shift from place to place without eating, their lips resting upon one another, or they may congregate with cattle, which are not subject to attack. The horses spend such days in awaiting darkness, after which feeding takes place. Characteristic positions of the animals are shown in Plate III.

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[1] See "Bibliography," page 50.

Wind with a velocity of 15 miles an hour or more greatly relieves the animals, and persons driving horses about thrashing machines often stop them so that they face the breeze.

Cloudiness is also a protection to horses, and if only a light cloud conceals the sun a bunch of horses may be observed to disperse and begin grazing. Often their feeding will have only begun when the sunlight returns, causing them again to seek protection in a group.

Horses in standing water are not annoyed by nose flies and frequently they seek this protection in order to eat, despite the fact that hundreds of mosquitoes feed upon each animal. This standing or feeding upon grass in water is excellent for a foundered horse, and the mud which adheres to his legs prevents *G. intestinalis* from ovipositing upon them.

While the wind and cloudiness are especially protective against *G. haemorrhoidalis*, the other two species of bot-flies are not much affected thereby. *G. intestinalis* may be observed to oviposit on windy and cloudy days. *G. nasalis* deposits under more adverse conditions than does *G. haemorrhoidalis*, but seems to be more sensitive to natural agencies than is *G. intestinalis*.

In barns the species of Gastrophilus never have been observed to oviposit. On numerous occasions ovipositing adults have been observed to pursue the animal only until it reaches the stall door. Post-mortem examinations of horses which had been confined in stalls failed to reveal a single larva. One of our correspondents reports that the annoyance of *G. haemorrhoidalis* was greatly reduced when he constructed a simple shed in the pasture where the horses could congregate.

## SEASONAL HISTORY OF GASTROPHILUS.

At Aberdeen, S. Dak., the larvæ of *G. haemorrhoidalis* are observed attached to the margin of the anus of horses as early as May 5 to 10, and if suitable temperatures occur adults may be expected a little prior to June 15.

From June 21 to 27, 1915, *G. haemorrhoidalis* adults appeared at Lodge Grass, Hardin, Billings, Miles City, and Custer, Mont. At the same time they appeared at Aberdeen, S. Dak., and neighboring points. They have been observed at Aberdeen, S. Dak., as late as October 10, though they are seldom found after a killing frost, which is usually about September 15.

The other two species appear at Aberdeen, S. Dak., about the same time as *G. haemorrhoidalis*, but are most abundant just before a killing frost. The *G. haemorrhoidalis* are least abundant at this time, and are present in greater numbers during the early half of the season. After a killing frost one seldom finds a Gastrophilus except when warm temperatures prevail during a few days.

In the "nose-fly" district one must bear in mind that the period during which flies oviposit is that when farmers are most busy, and the most favorable time for fly ovipositions is when the weather is most favorable for working horses. The adults appear during the plowing of corn and sorghum, and the annoyance continues during the mowing of hay, the harvesting and thrashing of grain, and the marketing of farm products.

## GASTROPHILUS HAEMORRHOIDALIS (Linnaeus).

### SYNONYMY.

*Oestrus haemorrhoidalis* Linnaeus, 1761.
*Gastrophilus haemorrhoidalis* Leach, 1817.
*Gastrus haemorrhoidalis* Meigen, 1824.

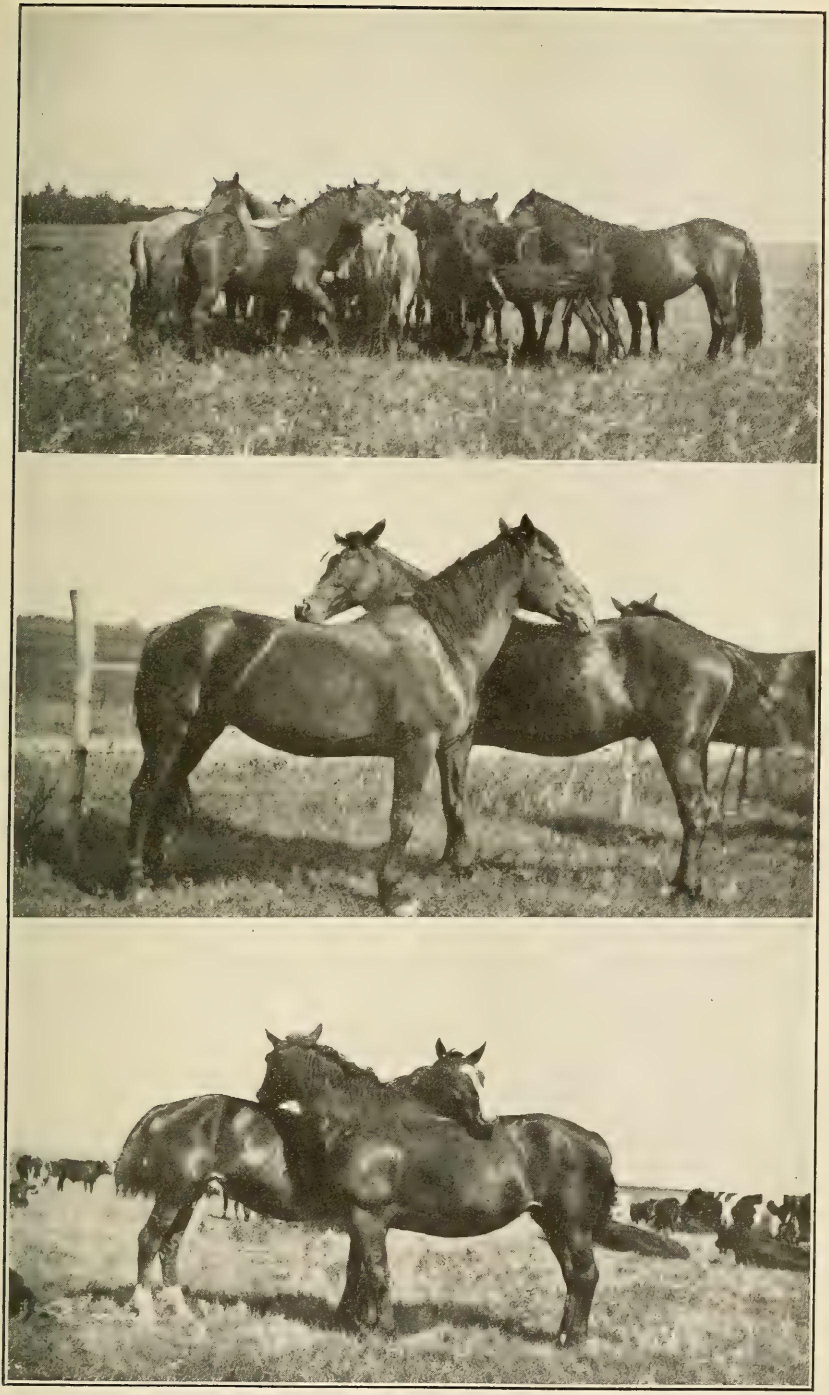
### ATTACHMENT IN RECTUM AND DROPPING OF LARVÆ.

During the early spring and summer the fourth-stage larvæ are normally concealed within the rectum, where lesions have been noted in post-mortem examinations. Later they effect a temporary attachment to the margin of the anus, where they become accustomed to the air temperatures, assume a greenish color, and apparently increase their motility. Larvæ, normally exposed to the air at the rectum, after dropping seem to conceal themselves at grass roots so as to be protected from the heat of the sun much more easily than those unexposed at the margin of the anus. When a larva is attached so that only the posterior end is exposed at the rectum one will find the anterior end a pinkish color, while the posterior will be greenish.

Larvæ exposed at the rectum have been observed for the length of time they remain attached, and the shortest period was slightly more than 40 hours, while the longest was 71 hours. The heat of the sun for a few minutes was sufficient to cause larvæ to drop when an attempt was made to photograph a larval attachment at the anus. At various times during the day larvæ appear at the anus, as many as 13 sometimes being visible at one time. The larvæ are likely to drop under most any condition, but do not drop with manure, as is supposed. When manure is dropped during their attachment they seem to use more effort in clinging and are only pushed aside during its passage. (See Plate I, figure at upper right.)

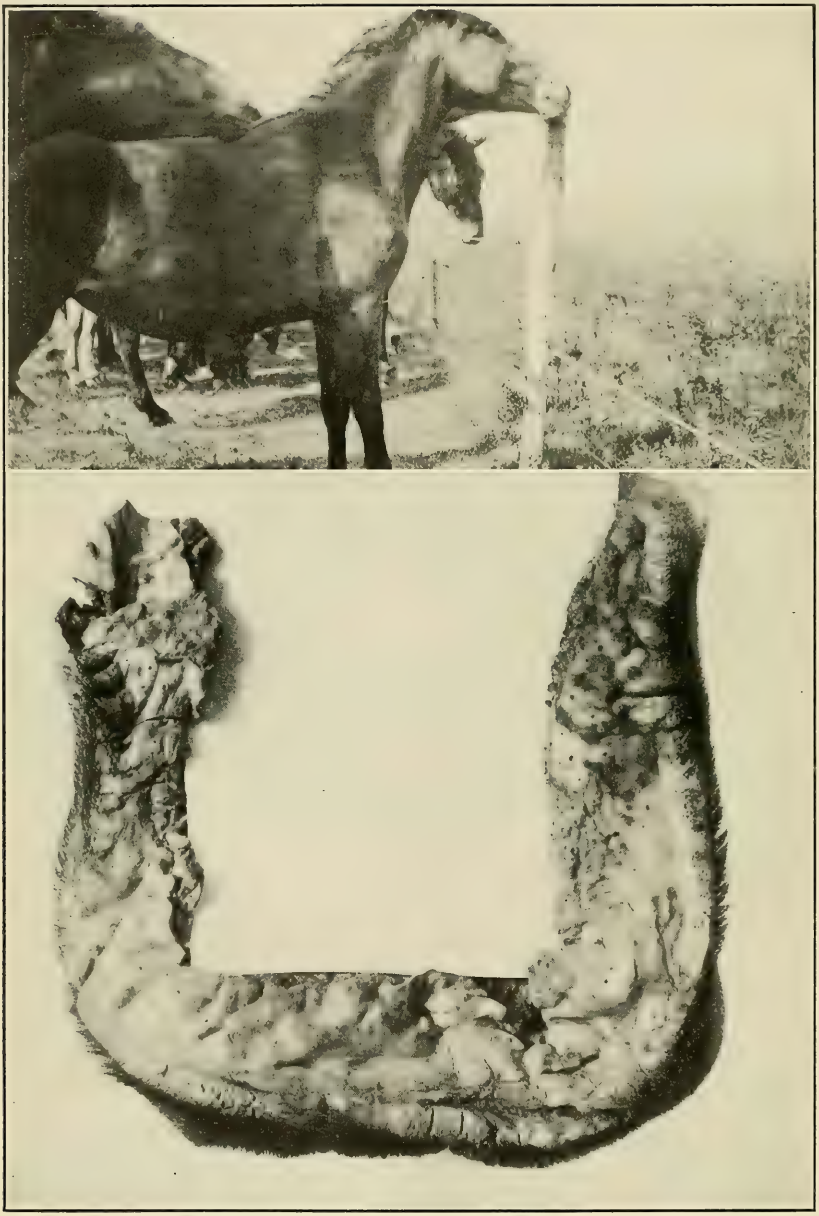
### PREPUPATION AND PUPAL PERIODS.

In the normal pupation of a larva which has been exposed at the margin of the anus there is a gradual change from greenish to yel-



PROTECTION FROM BOT FLIES.

Upper.—Horses assembled for protection during ovipositions of *Gastrophilus haemorrhoidalis*. Center.—A method of protecting lips from ovipositing *G. haemorrhoidalis*. Lower.—Protecting under jaws from ovipositing *G. nasalis*. (Original.)



SECONDARY INJURY FROM BOT FLIES.

Upper.—Horses rubbing following ovipositions of *Gastrophilus haemorrhoidalis*. Lower.—Lower lip of horse showing barbed wire cut at the lower extremity which resulted from rubbing. The small holes are injury from the grass *Hordeum jubatum*. (Original.)

lowish, the larva contracting and assuming the form of a pupa. As the puparium becomes more hardened a reddish tinge appears, but after a few days it becomes black and retains this color until the adult emerges.

TABLE II.—*Some environmental effects on metamorphosis of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak.*

| Larvæ collected from rectum. | Environment. | Prepupal period. | Pupal period. | Temperature, collection to emergence. | | | Number larvæ. | Number pupæ. | Number adults emerged. | Longevity of larvæ not pupating. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Max. | Min. | Mean. | | | | |
| 1915. | | *Hours.* | *Days.* | ° *F.* | ° *F.* | ° *F.* | | | | *Days.* |
| June 4 | Fresh horse manure in tin box | 27–47 | 39–45 | 88 | 35 | 63.21 | 14 | 14 | 10 | ...... |
| June 5 | do | 24–72 | 46–54 | 88 | 35 | 64.76 | 33 | 31 | 22 | 4 |
| June 7 | do | 34–52 | 37–44 | 88 | 35 | 64.93 | 16 | 13 | 8 | 8 |
| June 8 | do | 49 | 38–40 | 88 | 35 | 65.67 | 7 | 7 | 2 | ...... |
| June 9 | Clean tin box | 35–55 | 36–48 | 88 | 35 | 65.02 | 12 | 11 | 9 | ...... |
| June 12 | Glass jar and fresh horse manure | 53–146 | 33–36 | 88 | 40 | 65.73 | 14 | 14 | 5 | ...... |
| June 15 | Dry hard soil | 75–122 | 28–30 | 85 | 40 | 62.40 | 10 | 10 | 5 | ...... |
| Do | Moist horse manure | 122 | 29–31 | 85 | 40 | 62.56 | 10 | 8 | 7 | 15–22 |
| Do | Clean tin box | 120 | 31–32 | 84 | 40 | 62.89 | 7 | 6 | 4 | 15 |
| June 14 | do | 50–144 | 30–38 | 84 | 40 | 64.33 | 27 | 25 | 18 | 16 |
| June 18 | do | 27 | 32–42 | 84 | 40 | 63.23 | 34 | 30 | 26 | 12 |
| June 17 | Moist manure in tin box | 18–47 | 34–40 | 84 | 40 | 62.06 | 33 | 33 | 28 | ...... |
| July 12 | Black loam in tin can | 23–39 | 34–35 | 85 | 40 | 64.23 | 8 | 5 | 2 | ...... |
| Aug. 7 | On grass sod | 19–26 | 58–68 | 88 | [1] 32 | 60.59 | 7 | 7 | 3 | ...... |
| 1916. | | | | | | | | | | |
| May 22 | Clean tin box | 68 | 41 | 94 | 42 | 62.62 | 5 | 4 | 4 | ...... |
| May 23 | do | 52–72 | 36–40 | 94 | 42 | 62.81 | 5 | 4 | 3 | 11 |
| May 30 | do | 141–170 | 34–35 | 94 | 42 | 64.79 | 2 | 2 | 1 | ...... |
| May 31 | do | ........ | 35 | 94 | 42 | 60.08 | 1 | 1 | 1 | ...... |
| June 3 | do | 42–96 | 33–34 | 94 | 42 | 65.55 | 11 | 8 | 5 | 5 |
| June 5 | With moist sand | 75–100 | 32–35 | 94 | 42 | 66.69 | 17 | 17 | 16 | ...... |
| June 10 | do | 44 | 30–32 | 94 | 42 | 68.15 | 28 | 25 | 20 | 4 |
| June 23 | Clean tin box and moist loam | ........ | 21–24 | 96 | 48 | 74.08 | 46 | 44 | 38 | 5 |

[1] Minimum, Sept. 21.

In rearing larvæ to adults a most convenient and efficient method was utilized by placing them in clean tin salve boxes upon moist sand in bread pans. Table II gives some results of rearing under such conditions, using various media within the tin boxes. The period of collections extends from June 4 to August 7, which includes practically the entire season during which larvæ appear at the anus of horses in Aberdeen, S. Dak. It will be observed that the prepupal stage, the period from removal of larvæ until pupation, varies from 18 to 170 hours. This is a much greater range of time than is normal and may be attributed to the fact that larvæ were removed before the critical period of dropping. In some instances under varying conditions they did not pupate, and, while some larvæ died within a few days, one is recorded as living for 22 days.

The removal of larvæ from the rectum prior to their normal exposure to the air at the margin of the anus has a pronounced effect upon rearing. A small percentage have been reared which were fully developed and concealed within the rectum, but larvæ less than normal size, which were not exposed at the margin of the anus, did not produce adults. Only larvæ possessing the greenish color indicating exposure at the margin of the anus were used in experiments recorded in the tables.

In Table II, of 347 larvæ collected, 319 pupated and produced 236 adults, the pupa period varying from 21 to 68 days. The greater portion emerged during the shorter periods indicated in the table.

### FATE OF LARVÆ DROPPING UNDER VARYING CONDITIONS.

The variety of conditions under which larvæ are dropped naturally suggests the question of their ultimate fate. In an effort to determine this point by experiments, the most striking phenomenon observed was the larval "migration" which precedes pupation. In experiments recorded in Table III, larvæ placed upon the surface of the soil or media penetrated to a slight depth for protection of the pupæ. With larvæ buried in loose soil, as would ordinarily occur when they are dropped by plow horses, they moved upward to near the surface for pupation.

TABLE III.—*Natural pupation and artificial burials of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak., 1915–16.*

| Larvæ collected from rectum. | Environment. | Condition of soil. | Depth pupated. | Number larvæ. | Number pupated. | Adults emerged. | | Period, collection to emergence. | Temperature, collection to emergence. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Male. | Female. | | Max. | Min. | Mean. |
| 1915. | | | | | | | | *Days.* | ° *F.* | ° *F.* | ° *F.* |
| June 10 | On 2 inches fresh horse manure over 2 inches of loam. | Moist manure developed a mold. | Burrowed ½ to 1 inch in compact manure. | 17 | 17 | 7 | 5 | 35-41 | 88 | 40 | 66.10 |
| Do | On 2 inches dry horse manure over 2 inches of loam. | Very dry horse manure | Upon and near surface | 17 | 16 | 8 | 4 | 35-40 | 88 | 40 | 66.06 |
| June 15 | On dry, hard soil | Kept dry | At surface | 10 | 10 | 2 | 3 | 31-33 | 85 | 40 | 64.94 |
| Do | On moist manure | Kept moist | ½ to 3 inches deep | 10 | 8 | 2 | 5 | 34-36 | 85 | 40 | 64.93 |
| June 16 | Buried under 4 inches black loam and fresh horse manure intermixed. | Pulverized by Lachnosterna larvæ. | 3 pupated at surface | 15 | 14 | 4 | 4 | 31-40 | 85 | 40 | 64.03 |
| Do | Buried under 4 inches decaying straw and manure intermixed. | Fairly moist | Few near surface | 15 | 15 | 6 | 1 | 33-40 | 85 | 40 | 64.56 |
| June 19[1] | Buried under 3½ inches black loam. | Fairly moist and compact | 4 near surface | 35 | 35 | 6 | 9 | 30-35 | 85 | 41 | 64.91 |
| Do | On grass sod | Fairly moist | In crevices and near surface | 35 | 35 | 19 | 13 | 34-41 | 85 | 40 | 63.81 |
| July 9[2] | On wet black loam | Kept wet | Near surface | 17 | 8 | 1 | 1 | 35-36 | 85 | 40 | 63.95 |
| 1916. | | | | | | | | | | | |
| June 15[3] | On grass sod | Kept moist | Near surface | 21 | 19 | 1 | 2 | 32-34 | 96 | 42 | 70.74 |
| June 17 | Buried under 5 inches loam | Slightly moist | Pupæ placed 5 inches below surface. | 38 | 32 | 14 | 15 | 24-31 | 96 | 42 | 71.34 |
| July 10 | On grass sod | Kept slightly moist | Near surface | 43 | 42 | 20 | 18 | 23-24 | 98 | 53 | 71.66 |

[1] Pupæ decayed.

[2] 9 larvæ died; other pupæ decayed.

[3] Mouse ate contents of several puparia.

Questioning the fate of pupæ if buried, a lot consisting of larvæ that had moved near to the surface before pupating were replaced in moist loam to a depth of 5 inches. The adults had no difficulty in penetrating this soil, as 29 emerged normally from 32 pupæ. A lot of 15 larvæ buried 4 inches under black loam and fresh horse manure produced 14 pupæ, many of which were located near the surface. Lachnosterna larvæ were present and during their development kept the soil well pulverized. Of the 14 pupæ, 8 produced normal adults.

The experiments cited in Table III, with the exception of the lot of puparia eaten by a field mouse, show that the greater emergence percentage occurred when larvæ were placed upon grass sod. By this method sufficient moisture was supplied, and at the same time the movement of the larvæ to the roots of the grass protected the pupæ from excessive heat. In one lot 32 adults emerged from 35 pupæ, and in another, under similar conditions, 38 adults emerged from 42 pupæ.

It is also noted from other experiments that excessive moisture or dryness is less favorable for the metamorphosis.

## EFFECT OF HEAT ON LARVÆ AND PUPÆ.

Doubtless numerous larvæ and pupæ are subjected to heat, in barren places, when dropping from work horses driven upon the roads. This may not be confined to the heat of the sun, for horses standing in stalls may drop larvæ which are placed with the manure in piles that generate heat. The results of some tests are given in Table IV.

TABLE IV.—*Effect of heat on larvæ and pupæ of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak., 1915–16.*

| Date subjected. | Stage. | Number. | Environment. | Period of time subjected. | Temperature experienced. | | | Number pupating. | Number adults emerged. | Per cent death. | Period, collection to emergence. | Temperature after heat test. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Max. | Min. | Mean. | | | | | Max. | Min. | Mean. |
| 1915. | | | | | ° F. | ° F. | ° F. | | | | Days. | ° F. | ° F. | ° F. |
| July 5 | Larvæ | 10 | Glass jar with gauze cover, buried in manure pile. | 6 hours | | | 156.2 | | | 100 | | | | |
| Do | do | 5 | Buried in manure pile | 15 minutes | 152.6 | 150.8 | 151.7 | | | 100 | | | | |
| July 13[1] | do | 6 | In sun, black loam | 8 minutes | 122.0 | 121.1 | 121.6 | 6 | 2 | | 34–36 | 85 | 40 | 61.70 |
| July 31 | Pupæ | 4 | do | 30 minutes | | | 116.6 | 4 | 0 | 100 | | | | |
| Do | do | 4 | do | 62 minutes | | | 116.6 | 4 | 0 | 100 | | | | |
| Do | do | 4 | do | 98 minutes | | | 116.6 | 4 | 0 | 100 | | | | |
| Do | do | 4 | do | 137 minutes | | | 116.6 | 4 | 0 | 100 | | | | |
| July Check | | | | | | | | 5 | 4 | | 38–39 | 85 | 40 | 62.45 |
| Do | Pupæ | 8 | In sun on black loam | 137 minutes | | | 116.6 | 8 | 0 | 100 | | | | |
| Do | | | | | | | | 6 | 4 | | 38–39 | 85 | 40 | 62.48 |
| 1916. | | | | | | | | | | | | | | |
| July 3 | Larvæ | 3 | In sun on black loam | 8 minutes | 125.6 | 120.2 | 122.9 | 1 | 0 | 100 | | | | |
| Do | do | 3 | do | 10 minutes | 125.6 | 120.2 | 122.9 | 0 | | 100 | | | | |
| Do[2] | do | 4 | do | 12 minutes | 125.6 | 120.2 | 122.9 | 1 | | 100 | | | | |
| July 7[2] | do | 3 | do | 5 minutes | 131.0 | 125.6 | 128.3 | 3 | 2 | | 24–25 | 85 | 40 | 64.92 |
| Do | do | 4 | do | 7 minutes | 132.8 | 125.6 | 129.2 | 2 | 0 | | | | | |
| Do | do | 4 | do | 9 minutes | 132.8 | 125.6 | 129.2 | 1 | 1 | | | | | |
| Do[1] | do | 4 | do | 12 minutes | 132.8 | 125.6 | 129.2 | 2 | 2 | | | | | |
| Do | do | 4 | do | 14 minutes | 132.8 | 125.6 | 129.2 | 1 | 1 | | 26 | 85 | 40 | 66–61 |
| Do | do | 4 | do | 17 minutes | 133.7 | 125.6 | 129.7 | 2 | 1 | | 26 | 85 | 40 | 66–61 |

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[1] A fungus developed.

[2] Larvæ showed activity after subjection to heat.

Upon hard soil the larvæ are seldom observed to move more than a foot, and this sometimes requires 15 minutes. The tendency seems to be confined almost wholly to burrowing, and it is only when dropped on unsuitable places that they migrate. When exposed upon hard, barren soil to the heat of the sun during the summer it seems certain that only a few find protection and eventually produce adults. Certainly those not finding suitable protection from the sun's heat die within a short time. On black loam at a mean temperature of 122.9° F., 8 to 12 minute exposures caused 100 per cent mortality. Yet some larvæ seem to withstand even higher temperatures, for adults were produced after having been exposed from 5 to 17 minutes at a mean of 129° F. Pupæ, being unable to accommodate themselves by moving for protection, seem to be very susceptible to heat. Exposures of from 30 to 137 minutes at 116.6° F. were sufficient to render them inviable.

The heat generated in a manure pile produced greater mortality upon larvæ than ordinarily would be expected. Larvæ buried without protection at a mean temperature of 151.7° F. were dead within 15 minutes, having become soft and white.

### EFFECT OF SUBMERGENCE ON LARVÆ AND PUPÆ.

Although, as shown in Table III, excess moisture seems to have had a destructive effect upon pupæ, the effect of submergence upon larvæ is not so great. Larvæ submerged 51 to 74 hours pupated and produced adults. (See Table V.) Larvæ submerged for 80 hours pupated, but failed to emerge when kept under favorable breeding conditions. While it is difficult to submerge pupæ, as they float and expose a portion of the posterior spiracles, three normal ones kept in water for 5 days failed to emerge. In view of the results in Table III, it is apparent that great mortality occurs among pupæ during wet seasons.

TABLE V.—*Effect of submergence on larvæ and pupæ of Gastrophilus haemorrhoidalis at Aberdeen, S. Dak., 1915–16.*

| Date submerged. | Stage. | Number. | Period submerged. | Number pupated. | Adults emerged, (male.) | Larval longevity, including period of submergence. | Collection to emergence. | Temperature after period of submergence. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Max. | Min. | Mean. |
| 1915. | | | | | | *Days.* | *Days.* | °*F.* | °*F.* | °*F.* |
| July 5 | Larvæ | 6 | 51 hours | 4 | 3 | 5 | 36 | 85 | 41 | 63.93 |
| July 14 | do | 3 | 74 hours | 2 | 1 | | 38 | 85 | 41 | 64.21 |
| Do | do | 3 | 20 days | 0 | | 17–20 | | 85 | 41 | 62.95 |
| July 24 | do | 5 | 14 days | 0 | | 9–14 | | 80 | 40 | 58.14 |
| July 2 | Pupæ | 3 | 5 days | 0 | | | | 82 | 40 | 59.40 |
| 1916. | | | | | | | | | | |
| June 7 | Larvæ | 9 | 7 days | 0 | | 12 | | 76 | 43 | 64.83 |
| Do | do | 5 | 6 days | 1 | | 8–12 | | 76 | 43 | 64.83 |
| July 12 | do | 15 | 7¼ days | | | 8 | | 96 | 64 | 76.50 |
| Do | do | 5 | 80 hours | 5 | | 4 | | 96 | 64 | 75.90 |
| Do | do | 5 | 5¼ days | | | 7 | | 96 | 64 | 76.50 |

Larvæ have been observed to remain alive during submergence for from 14 to 20 days; those submerged 6 and 7 days live for some few days after removal.

## NATURAL CONTROL.

### FUNGUS DEVELOPMENT.

Under conditions the same as those upon which adults were reared in Table II apparently two species of fungi developed upon living material. The first mentioned in Table VI occurred upon three larvæ, to one of which a particle of horse manure adhered. They were collected from the rectum of perspiring horses, and it appeared that the fungus developed from the manure and spread to the larvæ and pupæ. The larvæ giving promise of fungus development were placed in a clean tin pill box with three well-washed *G. haemorrhoidalis* larvæ, which had been exposed to the air at the anus of a horse for about 24 hours preceding the washing. The fungus developed upon all the larvæ and death ensued. This fungus was determined by Mrs. Flora W. Patterson, Mycologist of the Bureau of Plant Industry, as *Sporotrichum minutum*. This, with one exception, was the only lot in which fungi appeared on living larvæ. As this fungus had developed upon larvæ collected from perspiring horses, it seemed possible that such larvæ as were not washed might have developed a superficial growth. Later collections were made from work animals which were perspiring during the time of collection, and they were kept under similar conditions, but no fungus appeared. In collections of larvæ kept under normal rearing conditions, as given in Table VI, a fungus appeared on the pupa stages which apparently spread to other pupæ in the same lot. In some lots pupæ remained without becoming infected, but in others it even developed upon various parts of the tin boxes. The collections and rearing methods used in these experiments were not unlike those in which no fungus appeared, as new, clean, but unsterilized tin boxes were used in each breeding experiment, and sterilized forceps were used in handling. The soil or medium was different in the various boxes, but since these various conditions were also present in lots which developed no fungi, there appears to be no reason for attributing it to the type of soil or to the medium. Upon the pupæ it appeared within from 3 to 17 days after collection.

TABLE VI.—*Fungus development upon pupæ of Gastrophilus haemorrhoidalis in new tin boxes at Aberdeen, S. Dak., 1915–16.*

| Larvæ from rectum. | Collection and environment. | Prepupal period. | Fungus appeared. | Pupal period. | Larvæ collected. | Larvæ pupated. | Number infected. | | Adults emerged | | Temperature collection to emergence. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pupæ. | Larvæ. | Male. | Female. | Max. | Min. | Mean. |
| 1915. | | *Hours.* | 1915. | *Days.* | | | | | | | °*F.* | °*F.* | °*F.* |
| June 11[1] | From perspiring horses | 79–220 | June 15 | 34–36 | 13 | 10 | 10 | 3 | 2 | 2 | 88 | 40 | 65.54 |
| June 15 | .... | 75 | June 30 | 35–38 | 10 | 10 | 10 | .... | 5 | 1 | 88 | 40 | 64.66 |
| June 21 | .... | 20–219 | June 25 | 30–32 | 34 | 29 | 29 | 5 | 7 | 6 | 85 | 41 | 63.88 |
| July 6 | With fresh horse manure | 6–25 | July 13 | 34 | 5 | 3 | 3 | .... | 1 | .... | 85 | 41 | 63.85 |
| Do. | From perspiring horse | 23 | .... | .... | 1 | 1 | 0 | .... | .... | .... | .... | .... | .... |
| July 7 | .... | 6–43 | July 13 | 33–36 | 3 | 3 | 3 | .... | 1 | 1 | 85 | 41 | 62.12 |
| July 10 | With moist loam | 5–18 | ...do. | 33–36 | 40 | 40 | 40 | .... | 14 | 11 | 85 | 41 | 64.32 |
| July 13 | .... | 21–29 | July 16 | 33–35 | 4 | 4 | 4 | .... | 1 | 1 | 85 | 41 | 64.43 |
| 1916. | | | 1916. | | | | | | | | | | |
| May 17[2] | On blotting paper | 22–32 | May 29 | .... | 7 | 7 | 7 | .... | .... | .... | .... | .... | .... |
| June 2[2] | .... | 20–39 | June 14 | .... | 13 | 11 | 11 | .... | .... | .... | .... | .... | .... |
| June 5 | .... | 77–102 | June 22 | .... | 2 | 2 | 2 | .... | 0 | 0 | 76 | 42 | 59.14 |
| Do.[2] | With moist sand | 48–72 | June 12 | .... | 8 | 7 | 7 | .... | .... | .... | .... | .... | .... |
| June 9[2] | ....do. | 22–70 | June 17 | .... | 10 | 10 | 10 | .... | .... | .... | .... | .... | .... |
| June 24 | ....do. | 4–122 | June 29 | 21–25 | 62 | 59 | 59 | .... | 24 | 15 | 96 | 48 | 74.67 |
| June 26[2] | .... | 19–166 | July 1 | .... | 20 | 17 | 16 | .... | .... | .... | .... | .... | .... |
| June 27 | .... | 22–190 | July 3 | 21–29 | 15 | 13 | 12 | .... | 4 | 6 | 96 | 56 | 75.73 |
| July 1 | .... | 3–6½ | July 6 | 20 | 4 | 4 | 4 | .... | .... | 1 | 96 | 58 | 77.07 |
| July 18[2] | With moist sand | 21–67 | July 25 | .... | 14 | 12 | 2 | .... | .... | .... | .... | .... | .... |
| July 24 | .... | 21–31 | July 28 | 29 | 19 | 18 | 18 | .... | 5 | 3 | 98 | 51 | 70.19 |

[1] Determined by Mrs. Flora W. Patterson as *Sporotrichum minutum.*
[2] Determined by Dr. A. T. Speare.

Except the collection on May 17, 1916, larvæ were not washed.

Several lots were sent to Dr. A. T. Speare, Mycoentomologist of the Bureau of Entomology, who made cultures and determined the characters showing that all the infestations were of one species and were not Sporotrichum.

According to Dr. Speare about 50 per cent of the pupæ sent to him produced adults. He reported that the fungus seemed to be restricted in its development to the chitinous wall of the puparium, and that death, if caused by the fungus, must have been brought about in some unusual way, as, for example, by closing the spiracles. However, the fungus seems to develop best at the rings of the segments and is seldom observed upon the posterior spiracles.

In Table IV it will be observed that a fungus appeared upon pupæ which had been subjected to heat tests, and this was apparently the same as has been observed in other experiments. A comparison of results and mortalities due to the fungi indicates that there is little hope of controlling the Gastrophilus by encouraging natural development of the fungus. Eighteen lots containing 283 larvæ produced 259 pupæ, of which 247 became infected with fungus in rearing experiments. Twelve of the lots, containing 194 pupæ, were retained for observations on mortality. Of these, 64 males and 47 females emerged as normal adults, giving 57 per cent emergence. The adults possessed a normal longevity as compared with others in rearing experiments.

The above percentage of mortality is based upon those experiments in which the fungus occurred. As there seems to be no reason for attributing the fungus to soil or media it is well to base this percentage upon all experiments in tin boxes and where pupæ were in close proximity. In Tables II and VI, 630 larvæ produced 578 pupæ. Of these 247, or approximately 43 per cent, developed a fungus. Of the ones kept under observation 57 per cent emerged, so that only 43 per cent of the infected pupæ were rendered inviable; 43 per cent of 43 per cent would approximate 18.5 per cent, or the percentage of loss in rearing experiments where numbers were kept in close proximity, which probably allowed the infection to spread over individual lots.

In Table III it is shown that no infected pupæ were found, and should a fungus develop in such conditions the single location of pupæ would prevent its spreading. This fungus has never been observed upon normal *G. intestinalis* or *G. nasalis*, though with dead larvæ of any Gastrophilus a long growth of fungus quite different from that met upon living *G. haemorrhoidalis* pupæ is frequently found.

### PREDATORS AND PARASITES.

The dropping of larvæ under varying conditions and in locations where they do not pupate in close proximity renders the situation such that very little could be expected of predators and parasites in control. In rearing experiments some field mice devoured pupæ on grass sod, but even though they feed upon these in nature it is not likely that a great many are devoured. Chickens probably do not feed upon many larvæ when they drop, though a single hen has been known to devour about 40 dead *G. intestinalis* removed from a horse by a carbon disulphid treatment, and without any noticeable ill effects upon the chicken.

Desiring to know if the widely distributed *Nasonia brevicornis*, which parasitizes various species of dipterous pupæ, could be reared upon *G. haemorrhoidalis* pupæ, repeated efforts were made, but without success. The indications are that the flycatchers feed very little upon Gastrophilus adults. On account of the danger in shooting such birds in pastures very few examinations of stomachs have been made.

## LIFE-HISTORY NOTES.

### ADULT LONGEVITY.

The life of adults appeared so short at the beginning of experiments that it was attributed to abnormal conditions, but various cages and environments did not materially increase the periods. A total of

254 males and 184 females were used in the experiments. All of these emerged normally from reared material. While some adults died on the first and second days the maximum longevity was 7 days. The greater periods were always obtained when the cages were kept out of the bright sunlight and provided with more or less foliage to prevent adults from battering themselves against the sides of the cage. Twenty-seven males and 15 females liberated in the insectary (9 by 12 by 7 feet) died within 1 to 3 days and were found dead at a sunny exposure with the wings battered. Cages admitting a great amount of light and without foliage yielded similar periods of longevity.

Adults in screen cages 18 by 18 by 18 inches or in a parasite-rearing box (covered on two sides with glass and arm holes in the ends) usually died within 3 days. This longevity was slightly extended when green twigs were frequently replenished.

The longest periods were obtained in wooden boxes 4 by 4 by 6 inches half filled with moist soil and provided with a green twig and a glass cover. This lessened adult activity, and from the 51 longevity experiments it was observed that the greater periods were always accompanied with the least activity, while the converse was also true. These wooden boxes placed in the shade admitted enough light to permit of activity and flies were often observed to fly about with the head near the glass and would alight on the green twigs and rest. The usual longevity under such conditions ranged from 3 to 6 days. Some adults captured in nature were kept under similar conditions and lived from 3 to 5 days.

Various flowers were supplied as food for the adults, but in no case was feeding observed. Sweepings were also made from flowers blooming in pastures and from alfalfa in bloom, but adults were never captured under such conditions.

### ADULT HABITS.

Adult flies in cages copulate most frequently about noon, the duration of the act ranging from 3 and 4 to 15 minutes. During the act the flies usually remain quiet, except for the distinct abdominal movements of the male. The male usually breaks from the female, leaving her at the place of copulation, but within a few minutes may be observed to return. One pair has been observed to copulate as many as four times within an hour. Males will mate with a freshly emerged female before her wings are dry, properly unfolded, or the body of a normal color. In nature the one object of the male seems to be copulation, and that of the female oviposition. Buzzing in midair about the horse the male may be easily caught with the hand. A female is only observed buzzing at a standstill in midair when a horse is grazing or otherwise protected from ovipositions. She usually comes from a distance and strikes at the lips. Her quick flight seems to be distinguished by the male, who attempts to mount her before she oviposits, but the momentum of the two usually carries the couple to some distant place so quickly that one can not tell whether copulation actually takes place upon the wing or whether they fall to the ground. At any rate, they fly for some distance. Apparently the sexes always meet at the horse, the males awaiting the approach of the females. At times the male encounters an adult female of *G. intestinalis* about the horse, and these two may be observed to fall upon the grass at the feet of the horse, usually separating within a few seconds.

### PREOVIPOSITION PERIOD AND OVIPOSITIONS.

Just how soon after emergence copulation takes place is not definitely known, but it is certainly less than 18 hours. Adults emerging during the night copulate by noon of the following day and will oviposit during that afternoon. They will not oviposit in captivity. On five occasions in which flies emerged normally during the night, males and females were kept in a box with glass sides and with green foliage. By noon in each case some were observed to copulate and when liberated in the afternoon would oviposit. Their wings were colored with red ink, and when captured they could be identified easily. Under favorable conditions ovipositions took place as soon as adults were liberated, usually about 3 hours after copulation. After a lapse of a few minutes they were never to be collected about the same bunch of horses, which is probably due to the migration of adults and to the movements of the various horses upon which they oviposit.

A determination of the egg-laying period is important in that it shows the value of destroying adults at different times during this stage, but with such short preoviposition and longevity periods and the inability of flies to feed, the indication is that the flies oviposit throughout their existence. Dissections of females reared to adults indicate that they develop from 134 to 167 eggs, the usual number possibly being near 150.

Unlike *G. intestinalis*, which may stand in midair and consecutively deposit 15 or 20 eggs at one time, often placing two or more upon one hair, *G. haemorrhoidalis* deposits but one at a time and only one upon a hair. It leaves the animal for about one-half minute or longer after ovipositing, but not for so long a time as does *G. nasalis*. It never oviposits upon any other portion except the lips, preferably the portions moistened by saliva. The stalk portion of the egg is inserted in the pore of the skin at varying depths, but the stalk has never been observed to be inserted for its full length. Often it extends to such a slight depth that after a few days the egg may be found lying lengthwise upon the lips, yet firmly attached to the hair. The color, a jet black, so conceals the attachment to the transparent hair that it appears that the hair extends through the center of the stalk portion and through a portion of the side of the egg. The extreme point, however, shows a folding about the hair which may be attributed to the pressure when it is inserted in the pore of the skin. Above the stalk portion the hair is attached to the side of the chamber containing the larva in a similar manner to the attachment of other Gastrophilus eggs upon the hair.

### INCUBATION AND INGRESS OF LARVÆ.

Having observed eggs upon both moist and dry portions of the lips of horses, large numbers in various stages of incubation were removed and placed in tubes for observation. About 100 were kept in a test tube, with a moist cotton stopper, at the air temperature of a living room. While a variation in color was at first observed, ranging from a black to a reddish color, after a few days the majority were of a reddish brown. Some were placed upon a slide and moistened, then by the use of two dissecting needles dead larvæ were removed. No larvæ had hatched of their own accord, but emerged when subjected to moisture and friction. In similar tubes which were kept dry three lots of eggs varying in color were observed and not a single larva hatched.

Examinations of the inside of horses' lips revealed numerous holes accompanied by much soreness which appeared as though the young larvæ hatched and had burrowed through the lips. Upon dissections in post-mortem examinations it was disclosed that the injury was caused by "wild barley" or "foxtail grass." This grass was determined by the Bureau of Plant Industry as *Hordeum jubatum*. Its injuries are more noticeable upon lips of livery horses when fed hay containing this grass, as pastured animals avoid eating it and the injury is less noticeable. It is worthy of note that this grass, in addition to its injury upon lips of horses, serves as a winter host of the black rust which is so destructive to wheat in the Dakotas.

On August 24, 1915, a suckling colt, its mother (a crippled horse) and another horse were carefully freed of eggs. Twenty-four hours later a diagram was made showing the exact location of each egg deposited during this time. Upon the following three days it was too cloudy for other adults to oviposit, so the horses were not kept in a barn to prevent further ovipositions, but were left to graze in the pasture. This allowed ample time for development of the embryo and of a distinguishing brownish-red color which greatly aided in keeping track of the eggs.

Upon the suckling colt the first egg disappeared upon the ninth day; the eleventh day, two; the thirteenth, five; and the fourteenth, six. Five other eggs about 1 inch from the mucous membrane and upon the dry portions yielded dead larvæ when examined.

Upon the lips of the cripple horse and within 1 inch of the mucous membrane 15 eggs were deposited. The first 6 eggs disappeared upon the seventh day from near the corners of the mouth. The last egg disappeared upon the eighteenth day.

The normal horse in grazing received 14 eggs within 1 inch from the mucous membrane. Upon the sixth day 10 eggs disappeared from near the corners of the mouth, which was probably five days from deposition. The other 4 disappeared during the following three days.

The striking feature of the above three cases is that those eggs deposited where they received most moisture and friction were the first to disappear. Prior to disappearance, the color changes, being first brownish, then a brownish red, finally with a whitish tip, thus clearly indicating embryonic development. It is also clearly seen that the amount of grazing affects the incubation, as the normal horse grazed practically the whole time, the cripple only at times, while the suckling colt was not observed to graze. There were no indications that the larvæ burrowed into the lips, and as well-incubated eggs have produced larvæ under moisture and friction when removed, it is certain that the method of ingress of larvæ into the host is not unlike that of *G. intestinalis.* It is true that eggshells were never found attached to the hairs after the larvæ had emerged, but it is believed the moisture and friction are sufficient to remove these after the larvæ leave the eggs and enter with the food.

Incubation records are not confined to the above three cases. Upon August 24, 1915, one other animal was freed of eggs and allowed to receive depositions during 24 hours. Upon the moist portions of the lips 17 eggs were found, while 6 were deposited upon the dry portions 1 inch from the mucous membranes. Separate notes give a comparative idea of the incubation. Upon the sixth day, probably 5 days from deposition, 4 eggs disappeared from the moist portions and others disappeared the following day. Upon the dry portions all were present upon the twelfth day. Three of these when removed contained dead forms and the other 3 disappeared from the eighteenth to the twenty-third day.

The day of oviposition in the above cases was favorably followed by three cloudy days, which prevented other ovipositions. The development of the embryo in eggs upon moist portions was quite in contrast to those upon the dry portions, showing clearly the necessity of moisture and friction. Such observations indicated that those eggs upon the moist portions incubated in from 5 days to a slightly longer period.

September 9 was preceded by two unfavorable days for oviposition and was itself very favorable, but was followed by rain and cloudy weather until September 15. At this time black eggs were found upon the dry portions of the lips, while upon the moist portions the eggs were reddish with whitish tips. Due to the scarcity of adults, the eggs were not plentiful at this time, and a few days later one only could be found, upon the dry portions of the lips.

Due to the comparatively long period during which the eggs remain attached upon the dry portions of the lips of horses, which is particularly due to the protection of the thick, coarse hairs surrounding them, it is believed that one could be misled easily as to the most favorable places of deposition of the adults.

## GASTROPHILUS NASALIS (Linnaeus).

### SYNONYMY.

*Oestrus nasalis* Linnaeus, 1761.
*Oestrus veterinus* Clark, 1797.
*Oestrus salutiferus* Clark, 1815.
*Oestrus clarkii* Leach, 1817.
*Gastrus nasalis* Meigen, 1824.
*Oestrus duodenalis* Schwab, 1840.
*Gastrophilus nasalis* Schiner, 1861.

### OVIPOSITIONS AND LONGEVITY.

The female *Gastrophilus nasalis* often appears from the grass about the fore legs of a grazing animal, strikes under the jaws, remains a few seconds, and during that time deposits an egg about midway upon the hair. The adult then leaves, completely disappearing in the distance, but within a minute or two a similar oviposition may occur, except that the adult approaches from a distance. The presence of a person about the head of an animal does not interfere with egg deposition, and the fly may be caught with the hand when it alights upon the hairs underneath the jaws. It may also be observed to deposit upon the fore legs or the flanks. Dissections of the abdomen of reared females show that they are capable of depositing from 480 to 518 eggs. The attachment of these, as may be seen by referring to figure 3, *c*, extends to almost the entire length of the egg, and being attached about midway upon the hair, numbers are concealed unless the hair is brushed aside in making examinations. Often eggs may be observed near the end of the hairs, but this usually occurs after great numbers have been deposited. Then it is possible to find two or more eggs upon one hair. As yet the method of ingress of the larvæ has not been determined. Dr. C. H. T. Townsend thinks that the larvæ burrow through into the mouth and are swallowed. One author believes that a horse in eating will rub the jaws upon the manger, which hatches the eggs, and that they are taken into the mouth with the food. The fact that some eggs are deposited upon the fore legs and portions accessible to the mouth indicates that the ingress of larvæ may be similar to that of *G. intestinalis.*

Longevity in this species seems to be increased over that of *G. haemorrhoidalis*, as one reared adult kept under conditions similar to those of the nose fly lived for 12 days.

### LARVA AND PUPA STAGES.

Coincidentally with the appearance of *G. haemorrhoidalis* at the anus of horses, the larvæ of *G. nasalis* occasionally may be observed to pass normally from horses and be found in their droppings. This normally occurs when larvæ become fully developed and is often attributed by farmers to " a destructive effect of grass upon the bots."

These larvæ seldom migrate a great distance, and apparently only burrow under the droppings for protection. Larvæ which dropped normally pupated in from 1½ to 2 days, though the prepupal periods in some cases in which larvæ were removed in autopsies and cited in Table VII extended for 7 days. It was observed that the short pupal periods were preceded by long prepupal ones, and that larvæ pupating within 2 days after dropping emerged in from 42 to 45 days. At Victoria, Tex., Mr. J. D. Mitchell collected a larva under manure, which pupated October 6, 1914, and emerged 20 days later. To rear larvæ collected in autopsies is a difficult task, even though they are well developed and appear normal, but during the late summer a small percentage may be reared if they are collected from horses immediately after death. The larvæ removed from dead animals are capable of remaining alive and active for some time, some having been kept as long as 25 days. Some larvæ have been observed to live submerged in water for 12 days.

TABLE VII.—*Pupal periods of Gastrophilus nasalis, Aberdeen, S. Dak., 1915–16.*

| Larvæ collected. | Location. | Number larvæ. | Breeding environment. | Number pupated. | Range of pupal period. | Number emerged. | | Longevity larvæ not pupating. | Temperatures. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Male. | Female. | | Maximum. | Minimum. | Mean. |
| 1915. | | | | | *Days.* | | | *Days.* | °*F.* | °*F.* | °*F.* |
| June 4 | Fresh dropping | 1 | With horse manure. | 1 | 42 | 1 | ...... | ...... | 88 | 35 | 65.30 |
| 1916. | | | | | | | | | | | |
| May 29 | .....do | 2 | Clean tin box; moist sand. | 2 | 44–45 | 1 | 1 | ...... | 94 | 42 | 67.93 |
| June 12 | Dropped from treatment. | 4 | .....do | 1 | 31 | 1 | ...... | 7 | 94 | 42 | [1]68.98 |
| July 10 | Duodenum | 19 | Dry paper in tin box. | 3 | 25–33 | 1 | 2 | 3–15 | 98 | 41 | 72.77 |
| Aug. 11 | Stomach | 18 | Moist sand | 3 | 48 | 1 | ...... | 3–8 | 98 | 28 | 60.26 |
| 11 | Duodenum | 18 | .....do | 3 | 56 | 1 | 1 | 11 | 95 | 28 | 59.97 |

[1] Horse treated with carbon disulphid.

## GASTROPHILUS INTESTINALIS (DeGeer).

### SYNONYMY.

*Oestrus bovis* Linnaeus, 1761.
*Oestrus intestinalis* De Geer, 1776.
*Oestrus equi* Clark, 1797.
*Gastrophilus equi* Leach, 1817.
*Gastrus equi* Meigen, 1824.
*Oestrus gastricus major* Schwab, 1840.

### OVIPOSITIONS AND LONGEVITY.

The universal distribution of the common bot-fly, the familiarity of innumerable persons with its oviposition habits, and the numerous publications dealing more particularly with ovipositions and ingress of the larvæ into the host since Bracy Clark (1797), leave little to be desired. It is probable that there is no other insect whose eggs come so directly under the observation of farmers as does the common bot-fly. The common names of this Gastrophilus vary with the locality, but farmers are usually aware of the fact that this insect produces the bots in horses.

Some authors contend that the eggs are deposited upon those places most accessible to the horse's mouth, while others hold that the fly will deposit upon any portion where it is not disturbed. It has always been observed that these flies give preference to the forelegs, and, after these have become well covered with eggs, depositions occur at other points where the fly is not disturbed by the horse's tail. Very few eggs are deposited upon the hind legs or upon the backs of the animals, but when adult flies are in numbers the mane may become heavily infested, especially near the shoulder. Large numbers of eggs may be found upon the sides of the animals, and these are concentrated at points accessible to the mouth, as in cases of depositions upon the inside of the forelegs. It seems that the fly oviposits on the forelegs instinctively, and, after the legs become heavily infested, adults may be observed to deposit one or two eggs on them and then seek other portions of the body. At times two or more eggs may be found upon a single hair on the inside of the forelegs, but seldom has this been noted upon other portions. However, the length of the mane often permits adults to deposit large numbers upon a single hair. With the exception of the forelegs, the sides below and to the rear of the shoulder blades probably harbor most eggs.

The longevity of 14 reared adults in 9 tests, in which the flies were kept under conditions similar to those employed in rearing *G. haemorrhoidalis* varied from 7 to 21 days. The longer periods occurred during early fall, when lower temperatures were experienced. These adults, like those of other species of Gastrophilus, were never observed feeding upon flowers, but green twigs were favorable resting places in rearing cages.

A female taken while ovipositing was placed within a tube containing a male, and they were observed to copulate for 5 minutes.

Dissections of 5 females showed the following egg capacity: Maximum, 770; minimum, 397; average, 541.

### INCUBATION AND INGRESS OF LARVÆ.

While making observations in pastures, on four occasions large numbers of eggs were collected which had been deposited upon the author's horse. The eggs were kept in tubes at air temperatures of a living room and none hatched without friction and moisture. By placing the infested hair upon a microscope slide and moistening it the larvæ were most easily removed by rubbing the lot with a dissecting needle. In such tests the eggs remained attached to the hair, while the operculum was removed, allowing the larva to emerge. Very good results were also obtained by rubbing a moistened finger over the lot. When eggs were less than 7 days old it was found difficult to obtain living larvæ, though at 9 and 11 days active larvæ were removed. When they were slightly older than 11 days they emerged without difficulty when attended by moisture and friction, and one living larva was found as late as the forty-eighth day. This seemed to be an exception, as in the other lots all were dead after 40 days. In general, all experiments tended to confirm those of Osborn. According to Guyot, with various lots placed in paper bags and kept in a pasteboard box at room temperatures, some emerged without moisture and friction. On December 28, 1900, Guyot obtained quite agile larvæ as late as 96 days after collection of the eggs. In another case, with eggs collected on October 6, he succeeded in obtaining larvæ from January 7 to 13 following, a period of 92 to 98 days. Due to this fact, Guyot concludes that the larvæ are capable of withstanding comparatively low temperatures after the eggs have been removed from the host. From eggs collected on horses in the open, active larvæ were removed as late as December 1.

### LARVA STAGES.

The attachment of young larvæ frequently occurs in almost any part of the stomach, but, as has been previously stated, they are found as fourth-stage larvæ upon the mucosa of the stomach, more especially on the left sac. If living larvæ are removed from an animal during a post-mortem examination a great tendency for reattachment will be observed. During such examinations they have been frequently separated into lots according to species, and in a short time they would attach to a piece of paper or stomach section or even to one another. This is only a temporary attachment, however, and apparently no attempt at feeding takes place.

The studies of Brauer, Numan, and Guyot indicate that the larvæ molt during their development and that there are at least three stages. No experiments have been reported as to the exact time that larvæ remain within the body of the horse, although apparently they spend about 10 months in this parasitic stage. On some occasions, as will be observed in Table I, well-developed larvæ were disclosed on post-mortem examinations in early fall. The indications are that some larvæ are not sufficiently developed to pass out in time to produce adults and that they succumb to low temperatures. There are various factors that apparently tend to influence the extension of larval periods. When gross infestations occur the development is markedly slower than in those horses containing only a few larvæ. Laxative foods have a greater tendency to discharge well-developed larvæ than foods of a non-laxative nature, as is observed in comparing autopsies of livery and pastured animals. Since there is such a wide range of variation in the ages of larvæ within the eggs at which they are capable of being ingested it is possible that this may tend to prolong the period during which the last-stage larvæ drop.

### SUBMERGENCE OF LARVÆ.

Last-stage larvæ removed from horses immediately after death remained alive and active from 21 to 33 days when submerged in water, but when submerged for only 6 days they would not attempt pupation. These periods are considerably decreased if larvæ are not removed shortly after the death of the animal.

### PUPA PERIODS.

The larvæ drop naturally with manure, burrow only enough for protection, and normally pupate within a day or two. The periods of dropping extend over a long time and very few larvæ are found in droppings. It is a difficult matter to rear larvæ taken in post-mortem examinations, and this is best undertaken in the late summer or early autumn, when the greatest number of larvæ are fully developed. With such larvæ, used in the experiments, the pupa periods have been observed to vary from 27 to 43 days, with an average of 38 days.

## EFFECT OF DEATH OF HOST UPON GASTROPHILUS LARVÆ.

The resistance of larvæ and the death of horses from infectious diseases naturally suggest the fate of larvæ during the period when they normally drop. In experiments larvæ were not kept with the animals during the decay, but were removed in autopsies, separated according to species, and placed under favorable rearing conditions. It is evident that larvæ within the stomach and duodenum are not capable of withstanding the internal processes which accompany the decomposition of animal tissues, especially during warm periods. There is excessive gas formation with the breaking down of the tissues, and the larvæ apparently become asphyxiated, since they are found bloated and when crushed become flat. During cool periods larvæ are affected very little for a number of hours, and in stated cases as long as 30 and 48 hours after death of the host larvæ have been reared to adults. Low temperatures hold back that period of decay in the carcass which normally would cause the death of larvæ.

From post-mortem examinations, as will be seen in Table I, *G. haemorrhoidalis* larvæ are seldom found in the rectum. In all probability they drop shortly after death, and during the normal period of dropping are capable of producing adults.

## CONTROL STUDIES.

### REMOVAL OF G. HAEMORRHOIDALIS LARVÆ FROM RECTUM.

The effectiveness of the extraction of Hypoderma larvæ as advocated by various authors suggests a mechanical removal of *G. haemorrhoidalis* larvæ. While they appear at the margin of the anus daily, studies show that they remain visibly attached from 40 to 71 hours. This would necessitate much work during a busy season with farmers, but extractions at feeding time would greatly reduce the number in work animals. In practice this periodical detaching caused much discomfort and soreness about the anus.

The attachment of clusters of larvæ within the rectum and the recommendation of tobacco decoctions, by the Bureau of Animal Industry (1911), for larvæ lodged in the rectums of horses, indicated the need of information as to the effect, on this species of Gastrophilus, of substances used as enemas. This necessarily required a detailed study of the effects of various substances upon larvæ, and these are reported in Table VIII.

TABLE VIII.—*Treatment of Gastrophilus haemorrhoidalis larvæ from rectums of horses, with contact insecticides, Aberdeen, S. Dak., 1915–16.*

| Number of larvæ. | Contact insecticides. | Exposure. | Immediate effects on larvæ. | Larvæ died. | Larval longevity after treatment. | Number pupating. | Pre-pupa period. | Pupa period. | Emergence. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Male. | Female. |
| | | | | | *Days.* | | *Days.* | *Days.* | | |
| 5 | Tincture quassia | 1 hour 10 minutes | Apparently none | 0 | | 5 | 1–5 | 35–36 | 1 | 2 |
| 5 | Essence ginger | 10 minutes | Hooks concealed | 0 | | 5 | 1–2 | 33–36 | 2 | 2 |
| 5 | Saturated solution borax[1] | 5 hours | do | All. | | | | | | |
| 5 | 10 per cent carbolic acid | 5 hours 15 minutes | Contracted | All. | | | | | | |
| 5 | Tar soap, soft | 4 minutes | Activity increased | All. | | | | | | |
| 5 | Tar soap, soft, and resin | do | do | All. | | | | | | |
| 5 | Saturated solution boric acid | 26 minutes | Contracted | All. | | | | | | |
| 5 | do | 10 minutes | None | 0 | | 5 | 1–2 | 33–34 | 2 | 2 |
| 5 | Beta naphthol, chloroform, soap, and water | 40 minutes | Inactive | All. | | | | | | |
| 2 | Hellebore and water | 2 days | | 1 | 12 | 1 | 6 | 44 | | 1 |
| 2 | Soft tar soap, water, and resin | 2¾ days | | All. | | | | | | |
| 4 | 3 per cent carbolic acid | 5 minutes | Contracted | All. | 7 | | | | | |
| 5 | 10 per cent carbolic acid | Posterior end dipped | Inactive | All. | | | | | | |
| 5 | do | 2 minutes | do | All. | | | | | | |
| 10 | Nicotine sulphate | do | do | All. | | | | | | |
| 6 | Nitrobenzine gas | 21 hours | None | 0 | | 6 | 2–4 | 28–29 | 2 | |
| 5 | do | 1 minute | do | All. | 1–6 | | | | | |
| 6 | Cresol, 2.7 per cent phenols[2] | do | do | All. | | | | | | |
| 5 | Cresol, 1.35 per cent phenols[2] | do | | All. | 6 | | | | | |
| 5 | Nitrobenzine | 2 minutes | | | | 5 | 1–3 | 26–28 | 2 | 1 |
| 4 | Cresol, 1.35 per cent phenols[2] | Posterior end dipped | None | | | 4 | 2–3 | 27–29 | 2 | 1 |
| 6 | Cresol, 0.45 per cent phenols[2] | 5 minutes | do | | | 6 | 3–5 | | 0 | 0 |
| 3 | do | 10 minutes | do | | | 3 | 1–3 | 26–28 | 1 | 2 |
| 3 | do | 15 minutes | do | | | 3 | 1–3 | 26–28 | 1 | 2 |
| 5 | do | 20 minutes | | | 6 | 4 | 1–3 | 26 | | 1 |
| 6 | Nitrobenzine | 4 hours | Inactive | All. | 4 | | | | | |
| 5 | do | 1 minute | None | All. | 7 | | | | | |
| 5 | do | 2 minutes | do | All. | 7 | | | | | |
| 5 | do | 3 minutes | do | All. | 7 | | | | | |
| 3 | 16⅔ per cent carbolic acid | do | Contracted | All. | | | | | | |
| 4 | do | 4 minutes | do | All. | | | | | | |
| 3 | 8⅓ per cent carbolic acid | 2 minutes | do | All. | 2 | | | | | |
| 4 | do | 4 minutes | do | All. | 2 | | | | | |
| 3 | 4⅙ per cent carbolic acid | 2 minutes | Soft | All. | 4 | | | | | |
| 4 | do | 4 minutes | do | All. | 4 | | | | | |
| 5 | 6⅔ per cent nicotine sulphate | 1 minute | None | All. | 2–4 | | | | | |
| 5 | do | 2 minutes | do | All. | 2–4 | | | | | |
| 5 | do | 3 minutes | do | All. | 2–4 | | | | | |
| 5 | 3⅓ per cent nicotine sulphate | 1 minute | do | All. | 2–9 | | | | | |
| 5 | do | 2 minutes | do | All. | 2–4 | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 3⅓ per cent nicotine sulphate | 3 minutes | do | All. | 2–9 | | | | | |
| 5 | 1⅔ per cent nicotine sulphate | 1 minute | do | All. | 2–9 | | | | | |
| 5 | do | 2 minutes | do | All. | 4–13 | | | | | |
| 5 | do | 3 minutes | do | All. | 2–9 | | | | | |
| 4 | do | 5 minutes | do | All. | 2–7 | | | | | |
| 4 | do | 12 minutes | do | All. | 4–9 | | | | | |
| 5 | do | 20 minutes | | All. | 4–9 | | | | | |

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[1] No effect from 10-minute submergence.

[2] Cresol suspended in resin soap.

Some of the tænicides and larvicides which have been successfully used upon insects, as well as soapy enemas, were tested upon detached larvæ in tin boxes. As with other Gastrophilus larvæ, remarkable resistance was noted. It will be observed that negative results were obtained by using the common tænicides, that soap solutions seemed more effective, and that nicotine sulphate gave good results.

### LARVAL TREATMENTS.

Experimenters have been impressed with the resistance of Gastrophilus larvæ to various contact substances, and it is practically agreed that any contact substance capable of killing the larva would seriously injure the stomach membranes of the horse. The internal method for use must necessarily be in the form of a fumigant. The use of carbon disulphid internally, as brought out by Perroncito and Bosso, has been tried and indorsed by many veterinarians. A list of indorsements from many countries can be found in articles dealing with this subject. Originally the disulphid was administered in 12-gram capsules surrounded by aloes, the whole contained in 48-gram gelatine capsules. In the hands of various workers it has been subjected to modifications, but each reports that large numbers of larvæ pass as a result of the treatment, and some remark upon the beneficial effects of the removal of larvæ upon the animal.

The Bureau of Animal Industry, after employing this treatment upon a number of horses, recommends the following procedure:

> The day preceding the treatment a small amount of hay and a moderate amount of oats is given in the morning; in the evening food is withheld and a purgative given—Barbados aloes 1 ounce, or raw linseed oil 1 pint. The day of the treatment, at 6 o'clock in the morning, give 3 drams of carbon disulphid in a gelatin capsule; at 7 o'clock repeat the dose in the same manner; and at 8 o'clock give the third and last dose, making in all 9 drams of carbon disulphid in three gelatin capsules.
>
> The above treatment is for the adult horse. For a yearling colt half the quantity of carbon disulphid used for a mature horse will give the desired results. If properly administered the gelatin capsule reaches the stomach intact, but soon dissolves and the carbon disulphid rapidly evaporates, suffocating all bot larvæ and other parasites with which it comes in contact, but not injuring the horse. Worms are quite often expelled as well.

The Bureau of Animal Industry calls attention to the fact that the so-called 4-dram capsules hold about 3 drams of carbon disulphid.

Desiring to know the periods of time required to kill the larvæ in the treatments, a number of experiments have been conducted in fumigating stomach sections to which larvæ were attached. Only larvæ from those animals that could be secured shortly after the death of the hosts were used, and the sections with larvæ in situ were placed in wooden boxes tightly covered with glass after the box was well moistened. The sections came from both the stomach and duodenum, and the tests include all three species of Gastrophilus. After the short periods of fumigation, which were ineffective with last-stage larvæ, it was observed that the larvæ lived for some days. At the end of fumigation tests it was impossible to determine the viability of larvæ except by observing them for a number of days. As will be seen in Table IX, chloroform was not wholly effective at 4 hours, but at a later date larvæ were killed with carbon disulphid within 3 hours. In no case did larvæ live after subjection to 3½ hours of carbon disulphid. These gases were liberated from absorbent cotton in the corner of the box, and no larvæ came in direct contact with the liquid, as would probably be the case within the stomach. The carbon disulphid, being soluble in water, evidently reaches all portions of the stomach, either as a gas or in solution.

TABLE IX.—*Fumigations of horse stomach and duodenum sections with Gastrophilus larvæ in situ, Aberdeen, S. Dak., 1916.*

| Post mortem and fumigation. | Species and number attached. | Exposure. | Fumigant. | Status at end of fumigation. | Mortality. | Longevity after fumigation. | Temperature since autopsy. | | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Maximum. | Minimum. | Mean. | |
| 1916. | | | | | | *Days.* | ° *F.* | ° *F.* | ° *F.* | |
| May 20 | 5 G. intestinalis | 1 hour | Carbon disulphid | Attached and active | All alive | 19–44 | 94 | 42 | 61.34 | Reattached to one another. |
| Do | 10 G. intestinalis | 1½ hours | do | do | do | 4–33 | 82 | 42 | 59.39 | Detached after fumigation. |
| Do | 17 G. intestinalis | do | do | do | do | 9–28 | 82 | 42 | 59.28 | Attached 40 hours. |
| Do | 5 G. intestinalis | 1 hour | Chloroform | do | do | 10–35 | 82 | 42 | 59.39 | |
| Do | 7 G. intestinalis | 1½ hours | do | do | do | 4–42 | 94 | 42 | 60.54 | Detached themselves after fumigation. |
| Do | 21 G. intestinalis | do | do | do | do | 16–44 | 94 | 42 | 61.34 | Attached 40 hours after fumigation. |
| Do | 2 G. nasalis | do | do | do | 1 dead | 0–9 | 79 | 42 | 58.50 | One reattached to paper in breeding box. |
| Do | 5 G. intestinalis | 1 hour | Benzine | do | All alive | 16–33 | 82 | 42 | 59.39 | |
| Do | 9 G. intestinalis | 1½ hours | do | do | do | 19–33 | 82 | 42 | 59.39 | Detached themselves after fumigation. |
| Do.[1] | 7 G. intestinalis | do | do | do | do | 17–30 | 82 | 42 | 59.03 | Attached 40 hours after fumigation. |
| Do | 1 G. haemorrhoidalis | do | do | do | Alive | 16 | 82 | 42 | 59.53 | Detached after fumigation. |
| May 29 | 6 G. intestinalis | 4 hours | Carbon disulphid | do | All dead | | | | | Attached 26 hours after fumigation, bloated. |
| Do | 19 G. intestinalis | do | do | Detached and inactive | do | | | | | Bloated less than larvæ remaining attached. |
| Do | 5 G. haemorrhoidalis | do | do | do | do | | | | | Did not bloat. |
| Do | 3 G. haemorrhoidalis | do | Chloroform | do | All alive | 16–21 | 82 | 43 | 59.48 | |
| Do | 3 G. intestinalis | do | do | do | do | 16–21 | 82 | 43 | 59.48 | |
| Do | 20 G. intestinalis | do | do | Attached and inactive | do | 19–24 | 82 | 43 | 59.65 | Attached to string in breeding box. |
| Do | 1 G. haemorrhoidalis | do | do | do | Alive | 21 | 82 | 43 | 59.48 | |
| June 8 | do | 3 hours | Carbon disulphid | Detached and inactive | Dead | | | | | Section of duodenum. |
| Do | 11 G. nasalis | do | do | 2 attached, all inactive | do | | | | | Do. |
| Do | 15 G. intestinalis | do | do | do | do | | | | | Bloated few days after fumigation. |
| Do | 4 G. haemorrhoidalis | do | do | All inactive, 1 attached | do | | | | | |
| July 11 | 19 G. intestinalis | 1 hour | do | Detached and inactive | Some alive | 3–13 | 96 | 58 | 74.90 | Fungus developed on dead larvæ. |
| Do | 1 G. nasalis | do | do | do | Alive | 8 | 96 | 60 | 76.87 | Do. |
| Do | 20 G. intestinalis | 2 hours | do | do | Some alive | 3–13 | 96 | 58 | 74.90 | Do. |
| Do | do | 3 hours | do | do | Dead (?) | | | | | Kept 13 days; 1 appeared alive tenth day. |
| Do | 40 G. intestinalis | 3½ hours | do | do | All dead | | | | | No life whatever. |
| July 24 | 406 G. intestinalis | do | do | do | do | | | | | 12 detached first 12 minutes. |
| Do | 111 G. nasalis | do | do | do | do | | | | | In duodenum, 20 detached first 12 minutes. |
| Sept. 16 | 37 small Gastrophilus | 2 hours | do | All inactive and some detached. | do | | | | | Appeared dead at 40 minutes' exposure. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Do.... | 2 Gastrophilus | ....do | ....do | Active when handled. | Alive | 11 | 80 | 28 | 53.23 | Larvæ detached at 40 minutes' exposure. |
| Do.... | 31 small Gastrophilus. | ....do | ....do | All inactive and some detached. | All dead | ........ | ........ | ........ | ........ | In duodenum, appeared dead in 40 minutes. |
| Sept. 18 | 19 small Gastrophilus. | 1 hour | ....do | All inactive and 7 attached. | ....do | ........ | ........ | ........ | ........ | |
| Do.... | 3 G. intestinalis | ....do | ....do | Inactive and detached. | Alive | 9 | 80 | 32 | 55.83 | |
| Do.... | 46 small Gastrophilus. | ....do | ....do | All inactive and 21 attached. | All dead | ........ | ........ | ........ | ........ | Section of duodenum. |
| Dec. 9 | 50 small Gastrophilus. | 45 minutes | ....do | Inactive and attached. | ....do | ........ | ........ | ........ | ........ | Fumigation at Dallas, Tex. |

[1] Two larvæ pupated 13 and 18 days after fumigation but did not emerge.

Except as otherwise indicated in "Remarks," larvæ were taken with stomach section.

The *G. intestinalis* are the most resistant of the Gastrophilus to treatments, but these, being found in the stomach, are in the most favorable place for treatment. No immediate effects of the gas upon last-stage Gastrophilus larvæ are observed, as they remain motionless for some time. Finally they contract so as to conceal the hooks of attachment and then drop from the stomach section. This sometimes occurs within 30 minutes after the fumigation begins, but most often it is after 1 or 2 hours. Occasionally the contraction is not so great and larvæ remain attached but drop at the slightest touch. A number of observations were made upon animals treated by local veterinarians. During the spring and early summer records were kept on 23 of these horses, which were treated when they contained only last-stage larvæ. The treatment was given as recommended by the Bureau of Animal Industry. Within 36 to 48 hours the first bots appear in the fæces, though if the physic acts well they may be found after 24 hours. The writer observed bots to pass for a period of 5 days, beginning about 36 hours after the treatment. With the first droppings a few living larvæ may be found which detached from the stomach before the treatment, and in one case *G. nasalis* was reared from such larvæ. *G. haemorrhoidalis* may appear at the anus as usual if this treatment is given in the spring, as by this time numbers have previously migrated to the rectum.

While Table IX shows that carbon disulphid gas is capable of killing last-stage larvæ within 3½ hours, the ideal time for treatment of horses would be in the autumn when all larvæ are young and the *G. haemorrhoidalis* are still within the stomach and duodenum. The last-mentioned experiments in Table IX show some fumigation results with small Gastrophilus. It will be observed that 1 hour was an amply sufficient time, though a few last-stage larvæ were present as late as September 18. If not caused to detach these would possibly drop during the winter and succumb to low temperatures. In Dallas, Tex., 45 minutes was sufficient to kill young larvæ on December 9, 1916.

The fact that *G. nasalis* attaches in the throat, where the larvæ are not in a position to be affected by the carbon disulphid treatment, emphasizes the fact that " an ounce of prevention is worth a pound of cure."

## REPELLENTS.

The rubbing of horses upon posts, bowlders, and other convenient objects suggested a device for use in pasture whereby horses could rub their lips upon a repellent. The short period of effectiveness of repellent substances and the inability to obtain one that will remain on the lips during grazing are difficulties which would seem to be overcome by such a device. A keg reservoir was devised whereby a flow of repellent, which was regulated by a stopcock, moistened a padded plank by means of a small pipe perforated with holes. This was placed at a salting and resting place of the horses and the amount of rubbing noted was very encouraging. Unfortunately, the horses did not rub the corners of the mouth, which are favorable places of egg deposition, and the scheme was abandoned.

Dr. Van Es suggested the use of a repellent upon the forelegs of horses and other portions of the body accessible to the mouth, so as to cause the common bot fly to deposit eggs upon places where they could not be reached by the horse's mouth. A marked repellent quality was observed in equal parts of pine tar and lard, no adults having been observed to oviposit during the following 4 days. There was apparently no injury to the animal, and 1 part of tar to 2 parts of lard was effective during 3 days. The disadvantage in some of the treatments was the fact that animals would walk through mud and water and cause a decrease in the repellent qualities of the mixture applied. Very good results were obtained with pine tar 3¾ ounces, kerosene 1¼ ounces, laundry soap 1 ounce, powdered resin 1 ounce, and hot water to make 14 ounces. The pine tar was thinned with kerosene, the soap and resin dissolved in hot water, and the two mixtures poured together. There was not only great repellent action observed, but the resin caused the hair to stick together in small bunches and prevented the adult flies from ovipositing. There was apparently no injury to the skin of the animal, and these same repellents prevented *G. nasalis* from ovipositing under the jaws. A successful repellent that would not require renewal over a reasonable period is desirable, since the loss of time due to the renewal of repellents is a great loss.

### MECHANICAL PROTECTIVE DEVICES FOR WORK HORSES.

The protective devices found upon work animals vary, but there are none used in the Dakotas on pastured animals. (See Plate V.) Various forms of fringes are most frequently found and may consist of leather, burlap, or a portion of the leg of trousers. These are probably the least effective of the devices, as examination of teams wearing such fringes developed the fact that they are often found infested with eggs. Leather seems to be the most efficient of the fringes, as it is not so easily blown aside by the wind and does not hinder the horses in breathing. Those extending completely around the head retail for 50 cents each, while those covering only the face sell for 25 cents.

Baskets which are used extensively in nose-fly districts serve as muzzles during the last plowing of corn, but are not very effective nose-fly protectors. The mesh is of sufficient coarseness to permit flies to oviposit if the lips can be touched. They do not always fit well at the top and occasionally a nose fly will get on the inside, producing great annoyance by its buzzing. During thrashing moisture collects within the basket and, when the dust settles upon this, creates a condition which greatly handicaps the animal's breathing. These baskets retail for 35 cents each when fitted with two snaps.

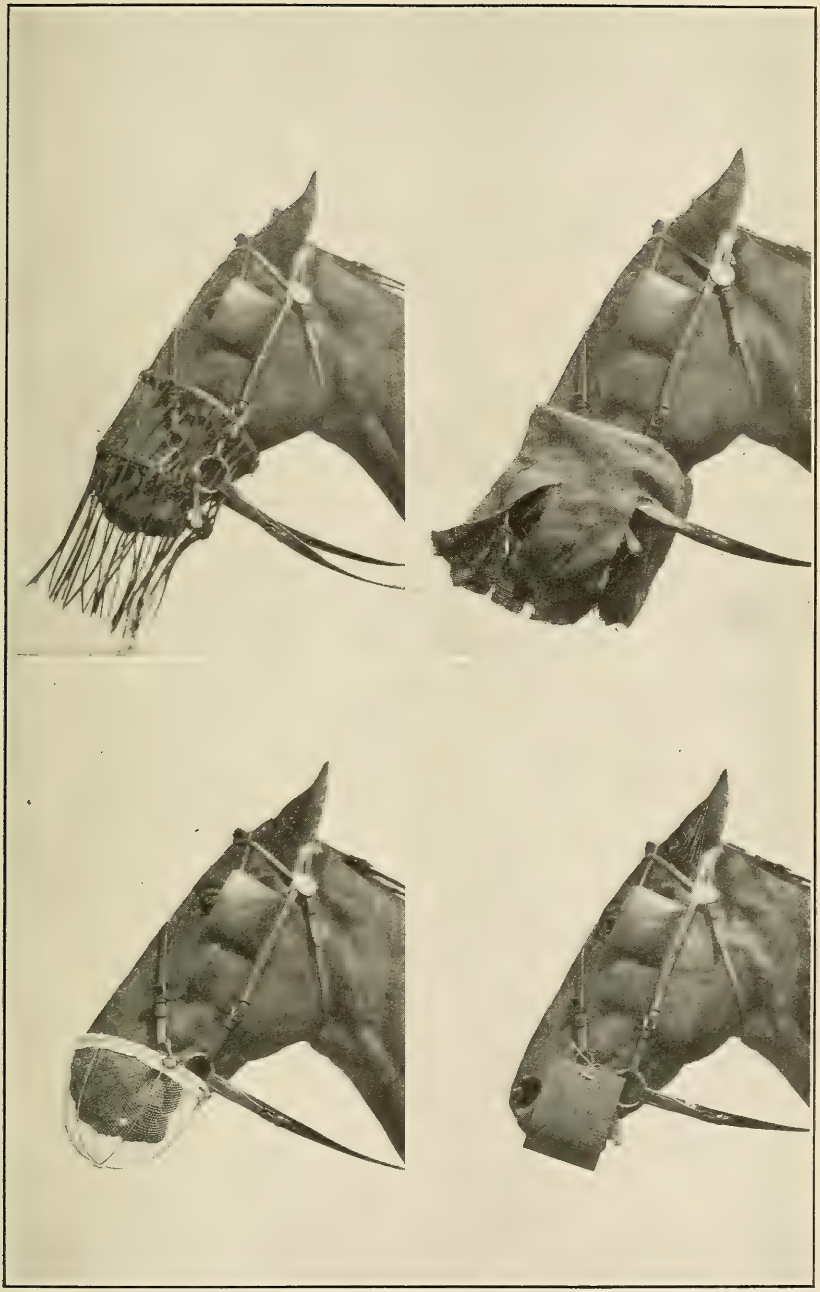
While protection of any description about the lips will prevent many ovipositions and annoyance by flies, by far the most effective device consists of a simple strip of leather extending over the lips and fastened at the bit rings. This actually covers the portions of the lips upon which the flies lay their eggs and upon horses thus protected an absence of eggs and annoyance has been noted. During the movement of the horse's head in walking, especially when working, this protection not only covers the lips, but swings to and fro and tends to repel the flies. The nostrils being exposed, it does not hinder breathing. Due to the cost of leather, very few of these are in use, but if one obtains an old belt from a thrashing machine great numbers can be made. It requires only a strip which will extend from one bit ring to the other and be from 4 to 6 inches in width. The size of the strip will depend upon the size of the horse's head. A snap placed at each end near the center facilitates handling, and the protector can be snapped onto the harness when not in use.

### PROTECTORS FOR PASTURED ANIMALS.

Studies of efficiency of halter appliances for pastured horses have been made, and while conclusive results have not been obtained, a type has been designed which promises to meet the demand. At first halters were used with a piece of leather covering the jaws and hanging so as to flap against the lips when the animal walked. The front of the halter was provided with a face net which swung over the nostrils and lips. This proved unsatisfactory, as the flap, if long enough to protect the animals during depositions, was too long during grazing. The horses would step upon them with the fore feet, causing them to break.

A variation from the most efficient work-horse protector was devised by using a piece of duck on the rear, so as to cover the jaws and prevent *G. nasalis* from depositing in this location (see fig. 4). A block of wood under the center and below the lips enables a horse to graze with ease and at the same time be protected from flies when the head is held above the ground. The cloth on the rear also prevents ingress of *G. intestinalis* larvæ by preventing the horse from scratching portions infested with eggs. When the head is placed upon other animals the device occasions such discomfort that almost immediately the horses move and prevent the protected animal from becoming infested from their bodies.

For pasture uses the leather becomes soft and at times exposes the corners of the mouth, but excellent results have been obtained by sub-



DEVICES IN USE TO PROTECT WORK HORSES FROM OVIPOSITING G. HAEMORRHOIDALIS.

Upper left.—A leather fringe is fairly effective. Upper right.—A burlap fringe hinders breathing. Lower left.—A wire basket often permits ovipositions on account of coarse mesh and ill fitting. Moisture and dust collect and hinder breathing. Lower right.—A strip of leather actually covers oviposition places and allows the horse to breathe easily. (Original.)

stituting a hard wood. The weight in either case will compare with the weight of blind bridles. Horses using these in experiments became free of *G. haemorrhoidalis* eggs during the summer of 1916, whereas unprotected animals were heavily infested. There was also a marked difference in the feeding, as protected animals grazed normally in bunches. While the device indicates a favorable preventive measure, before its adoption tests of durability should be made and minor points in the construction determined. It seems possible that the construction could be made so simple that farmers could make the protectors at a nominal price.

A halter attachment would permit horses to graze during times that are favorable for depositions of flies, and would prevent eventual infestations by all three species of Gastrophilus. A shed constructed in the pasture would protect animals from nose flies, although it would not prevent infestations by the other species of Gastrophilus. Such a shed would keep the animals from grazing during times that were favorable for depositions, and could be used for storage of feed during the winter.

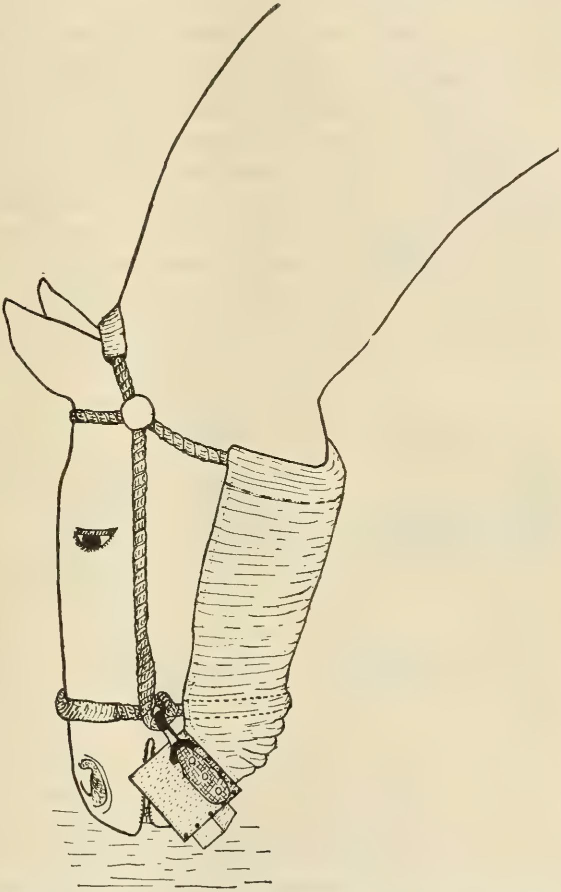


Fig. 4.—A bot preventive. The box prevents "nose flies" from ovipositing when the head is held upright, while the block of wood underneath the box allows the horse to graze easily. The canvas prevents normal ovipositions of the "throat bot-fly," and does not permit the horse to bite the portions infested with eggs of the "common bot-fly." (Original.)

### EFFECTIVENESS OF WASHES UPON EGGS.

Regardless of whether horses are treated internally for bots, which is best during the autumn, when larvæ are small, or whether they wear halter appliances during the summer, it is necessary to treat the eggs during the autumn to prevent a late infestation from the well-incubated eggs after the protectors have been removed. Then, too, the ease with which places so accessible to the horse's mouth can be washed makes the use of washes a practical prevention in regions where bots are not so numerous.

### LARVÆ REMOVED FROM EGGS PRIOR TO TREATMENT.

Active larvæ were removed from well-incubated eggs and subjected to substances reported in Table X. Only larvæ in excellent condition were used, and these were observed in watch glasses, small tin boxes, and test tubes at short intervals until dead. When in doubt they were removed with a drop of the liquid to a microscope slide, and the warmth of one's breath was sufficient to cause living ones to move. Larvæ were killed instantly when placed in volatile liquids or gases of carbon disulphid and in absolute alcohol.

TABLE X.—*Resistance of first-stage larvæ of Gastrophilus intestinalis, Aberdeen, S. Dak., 1916.*

| Larvæ placed in— | Longevity. | Larvæ placed in— | Longevity. |
|---|---|---|---|
| Dry tin box | 72 to 126 hours. | Borax, saturated solution | 40 minutes. |
| Water | 76 to 99 hours. | 50 per cent alcohol | 30 minutes. |
| Tincture quassia | 24 to 36 hours. | Petroleum, refined | 30 minutes. |
| Beta-naphthol in alcohol | 20 to 28 hours. | Do | 30 minutes. |
| 10 per cent oil of tar emulsion | 41 to 48 hours. | Boric acid | 13 minutes. |
| Borax, saturated solution | 28 to 41 hours. | 33⅓ per cent pine tar and 66⅔ per cent kerosene. | 1 minute. |
| Do | 24 to 43 hours. | | |

Dr. Guyot's results compare favorably with those herein reported. His larvæ remained alive in water for 4 days, nearly a day in olive oil, and more than 14 hours in bichlorid of mercury solution 1 to 1,000.

The movement of freshly emerged larvæ is very rapid upon moist surfaces, but upon a dry surface they seldom move from the original location, although they have been observed to live for 72 to 125 hours. When placed in water the larvæ became submerged with the exception of the posterior spiracles, which remained exposed at the surface. They are capable of living in this manner for 76 to 99 hours.

### LARVÆ REMOVED AFTER TREATMENT OF EGGS.

Hundreds of eggs were collected from horses in pastures during the latter part of August and the early half of September. At this time the activities of adults of *G. intestinalis* were being directed to the manes of horses for oviposition, as in most cases the inside of the forelegs and sides immediately behind the forelegs were very grossly infested. These hairs were of sufficient length to render handling easy, and the eggs were about the same age. Except as otherwise indicated in Table XI, infested hair was placed in tubes at air temperatures of a living room and allowed to remain until larvæ were well formed and ready for emergence. Some of the eggs were then tested and the viability determined. A check was not kept, as the brownish color of the dead larvæ easily distinguished them from the transparency of the active larvæ.

TABLE XI.—*Effectiveness of washes upon eggs of Gastrophilus intestinalis, Aberdeen, S. Dak., 1915–16.*

| Date eggs treated. | Insecticide. | Exposure. | Number larvæ examined. | Mortality of larvæ. | | | Remarks. |
|---|---|---|---|---|---|---|---|
| | | | | Dead. | Living. | Doubtful. | |
| 1915. | | *Minutes* | | | | | |
| Sept. 6 | Refined petroleum | 6–18 | 7 | 0 | 7 | 0 | Engine oil, No. 1. |
| Do. | do | 18–31 | 8 | 4 | 4 | 0 | Do. |
| 1916. | | *Hours.* | | | | | |
| Sept. 7 | Kerosene | 24 | 20 | 19 | ........ | 1 | |
| Do. | 1.35 per cent phenols[1] | 24 | 38 | 38 | 0 | 0 | Reddish brown in color. |
| Do. | 2 per cent nicotine sulphate. | 24 | 17 | 12 | 5 | 0 | |
| Do. | Carbolic acid 2 per cent phenol. | 24 | 20 | 19 | 1 | 0 | |
| Do. | Lard | 24 | 20 | 0 | 20 | 0 | |
| Do. | Nitrobenzine gas | 25 | 38 | 38 | 0 | 0 | |
| Sept. 9 | Carbolic acid 2 per cent phenol. | 5 | 28 | 23 | 0 | 0 | 2 larvæ yellow in color. |
| Do. | Kerosene | 29 | 22 | 5 | 17 | ........ | 5 dead larvæ yellow in color. |
| Do. | 0.135 per cent phenols[1] | 29 | 23 | 23 | 0 | 0 | 3 dead larvæ yellow in color. |
| Sept. 11 | Nitrobenzine gas | 4 | 34 | 7 | 22 | 5 | |
| Do. | do | 10 | 40 | 37 | ........ | 3 | |
| Do. | do | 25 | 42 | 42 | 0 | 0 | |
| Do. | 0.054 per cent phenols[1] | 26 | 40 | 40 | 0 | 0 | |
| Do. | Kerosene | 25 | 28 | 5 | 23 | ........ | 18 larvæ very active. |
| Do. | 2 per cent nicotine sulphate. | 26 | 26 | 9 | 14 | 3 | |
| Do. | 2 per cent carbolic acid | 26 | 38 | 38 | 0 | 0 | |
| Sept 15[2] | Kerosene | 24 | 55 | 11 | 38 | 6 | 38 larvæ very active. |
| Do.[1] | Carbolic acid 2 per cent phenol. | 24 | 48 | 47 | 0 | 1 | |
| Do.[1] | 0.054 per cent phenols[1] | 25 | 49 | 49 | 0 | 0 | |
| Do.[1] | Kerosene | 147 | 24 | 3 | 19 | 2 | |
| Do.[1] | Carbolic acid 2 per cent phenol. | 146 | 27 | 27 | 0 | 0 | |
| Do.[1] | 0.054 per cent phenols[1] | 147 | 21 | 21 | 0 | 0 | |

[1] A proprietary compound of cresol in combination with resin soap.
[2] Eggs not well incubated were treated and larvæ removed Sept. 21.

In the tests with larvæ removed from the eggs it was observed that the minimum period causing death by contact was 1 minute with pine tar 1 part and kerosene 2 parts. The ease with which either of these can be obtained suggested a study of these and similar substances.

It will be observed that kerosene, which is commonly reported to be in use by farmers, even at an exposure of 147 hours, had practically no effect upon larvæ. When eggs upon hair were rubbed they more readily yielded to hatching and apparently the larvæ were more active than from any similar treatment. The kerosene seemed to facilitate the emergence of the larvæ. While it was ineffective against well-developed larvæ, it was thought that upon freshly deposited eggs it would probably prevent development of the embryo, as is the case with hens' eggs during incubation; but even a test of this kind was only slightly effective.

A 2 per cent nicotine-sulphate solution was only partially effective. Nitrobenzine gas, which has recently been brought to our attention as a fumigant for external parasites of animals by Prof. William Moore, of the University of Minnesota, yielded good results at 25, 24, and 10 hours' exposure, but only a small percentage was killed at 4 hours. The fumigation was conducted in a common glass fruit jar into which a strip of cloth, impregnated with a few drops of nitrobenzine, was suspended.

The phenol compounds, by a contact application, seem to be most effective in destroying young larvæ and preventing the further development of embryos. It will be observed that carbolic acid containing 2 per cent phenol yielded as good results as higher percentages, and that this substance was most effectively used.

With carbolic acid as a wash it will be well to be cautious of its effects upon the hands. If used at too great strength, the exposed skin of the hand will become white and peel off, although it does not affect the skin of the horse, which is protected by the hair.

## SUMMARY.

Three species of horse bots—the common bot-fly (*Gastrophilus intestinalis*), the throat bot-fly (*G. nasalis*), and the nose fly (*G. haemorrhoidalis*)—occur in the United States, and each is a source of considerable injury to horses. This injury is produced through worriment caused by the flies at the time the eggs are laid and by the attachment of the larvæ, or bots, in the alimentary tract.

*Gastrophilus intestinalis* and *G. nasalis* are widely distributed in the United States but *G. haemorrhoidalis* is confined to the North-Central and northern Rocky Mountain States.

The nose fly (*G. haemorrhoidalis*) is by far the most annoying to horses at the time its eggs are laid. The adults appear early in June and reach the maximum of abundance during the first half of the season, disappearing with killing frosts. The eggs are deposited on the minute hairs on the lips, and those near the edges which are kept moist and receive friction hatch in from 5 to 10 days. The larvæ are taken in with food or water and attach themselves to the walls of the stomach. Here they remain until the following winter or spring and then migrate to the rectum, where they reattach. Before leaving the host they usually attach close to the anus and protrude from it. They remain in this position from 40 to 71 hours. After dropping to the ground the bots seek protection and pupate in from 18 to 170 hours later. The pupa stage lasts from 21 to 68 days. The adults are very active, and as they deposit only one egg at a time they are not so frequently seen about horses as are the adults of the common bot-fly. They take no food in the adult stage. Their length of life is from 1 to 7 days.

The throat bot-fly (*G. nasalis*) deposits its eggs on the hairs under the jaws and to some extent on the shoulders and other parts of the host. The larvæ of this species attach themselves to the walls of the pharynx and also to those of the stomach and duodenum. They do not reattach in the rectum or at the anus as do the bots of the nose fly. Pupation occurs in from 1½ to 2 days after the larvæ have passed from the host, and adults emerge in from 20 to 56 days later. The adults are somewhat longer lived than those of the nose fly. The flies cause considerable annoyance to horses during oviposition but not as serious as in the case of the nose fly.

The common bot-fly (*G. intestinalis*) usually appears later in the season than the nose fly and becomes most abundant just before killing frosts. The eggs are deposited on all parts of the body, but preferably on the fore legs. They hatch upon the application of moisture and friction. From 9 to 11 days after oviposition appears to be the most favorable period for hatching, although some may hatch as early as 7 days and others as late as 96 days after oviposition. The larvæ attach in any part of the stomach, but the last-stage bots are found mostly in the left sac. They continue to drop from the host for a long period of time. Pupation takes place in protected places on the surface of the soil and the pupa stage lasts from 40 to 60 days.

All Gastrophilus larvæ are surprisingly resistant to chemicals. The treatment of horses with carbon disulphid in three doses followed by a physic is satisfactory if administered in the late fall. Spring treatment is less effective, as the full-grown larvæ are more resistant, and many of the nose-fly bots have left the stomach and passed back to the rectum at that time.

Larvæ of *G. haemorrhoidalis* may be removed from the rectum mechanically, but this is laborious. The use of enemas containing insecticides is ineffective.

As a repellent, pine tar mixed with other material gave good results against the common bot-fly and the throat bot-fly. Such mixtures may be utilized to cause the flies to lay eggs on parts of the body less accessible to the horse's mouth.

Various nose protectors are in use against *G. haemorrhoidalis*, but there are objections to many of them. A piece of leather suspended below the lips from the bit rings is simplest and best. For animals on pasture a halter with a box-like arrangement and throat cover has been devised to protect horses against infestation by all three species.

Kerosene oil used as a wash is ineffective in destroying the eggs of Gastrophilus, but certain other substances have given good results. Carbolic acid containing 2 per cent phenols is satisfactory for destroying eggs when applied to the infested parts of the host.

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UNITED STATES DEPARTMENT OF AGRICULTURE

# BULLETIN No. 598

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER. February 4, 1918

# ORCHARD INJURY BY THE HICKORY TIGER-MOTH.

By DWIGHT ISELY, *Scientific Assistant, Deciduous Fruit Insect Investigations.*

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## INTRODUCTION.

The injurious stage of the hickory tiger-moth, *Halisidota caryae* Harris,[1] is a gregarious summer caterpillar (Pls. I, II) which, although a general feeder on deciduous trees and shrubs, causes occasional injury in orchards of pomaceous fruits and cultivated walnuts. While in this respect it is a minor pest, its injury, where it occurs, is severe and conspicuous and is the source of frequent inquiries to the Bureau of Entomology and to entomologists in the field. The writer's attention was frequently called to the work of this caterpillar while stationed at North East, Pa., during the seasons of 1914, 1915, and 1916, and there, incidental to the major projects then under investigation, the seasonal history and habits of this insect have been studied and the necessary remedial measures determined.[2]

## HISTORY.

Injury by the hickory tiger-moth was first described by Harris in 1841 (1) in the earliest important work on economic entomology published in America. Since then frequent reports of local outbreaks have been recorded in entomological literature. Complaints have been made to the Bureau of Entomology regularly since 1870, and specimens and records of injury have been received annually since 1904. Yet in spite of this constant occurrence there appear to be no records of very great destructiveness. The nearest approach to a general outbreak recorded occurred in 1907, when the bureau received numerous complaints from New England as well as scattered reports from other parts of the United States and from Canada. When Harris (1)[1] first described the adult, larva, and pupa as *Lophocampa caryae*, he gave in addition a brief account of the larval feeding and cocoon-making habits, and listed hickory, elm, and ash as food plants. Fitch (2) in 1855 gave a further account of larval habits and added butternut, sumach, and slippery elm to Harris's list of food plants; and during this same year the species was listed by Walker (3) and figured by Herrich-Schäffer (4). In 1882 it was listed by Grote (5). Few biological data were added until Beutenmüller (6) in 1890 listed 32 food plants of the hickory tiger-moth. The same year Dyar (7), in discussing head measurements of lepidopterous larvæ, recorded nine larva stages of *H. caryae*. Soule (8) in 1891 first described the egg and gave life-history records from egg to pupa, but recorded only seven larva stages. Packard (9) in 1893 also described the egg and larva stages and of the latter recorded only five. Eliot and Soule (11) in 1902 gave a popular account of the life history similar to the previous one by the junior author, and this later account is the most nearly complete record of its biology.

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[1] Order Lepidoptera, family Arctiidae.

[2] The writer was assisted in 1915 by E. R. Selkregg and in 1916 by James K. Primm.

From 1905 to 1908, inclusive, the period when inquiries made to the Bureau of Entomology regarding this insect were most frequent, there were a number of brief references to it by economic entomologists in the northeastern United States. These references were brief and added little to the published records except to note its economic importance. Patch (12) mentions it as a late summer feeder, Felt (13 and 15) records it as of economic importance in New York, Sanderson (14 and 19) records it among apple insects of New Hampshire, Britton (16) refers to it as abundant in Connecticut, and Gibson (17) records an unusual outbreak for two years in several Canadian Provinces. Dr. L. O. Howard states that this species was unusually abundant in Greene County, N. Y., in September, 1917.

## COMMON NAME.

This insect was called the hickory tussock moth by Harris (1), and until a comparatively recent time this name has been used. Comstock (10) called it the hickory tiger-moth. The latter name would seem preferable, since the insect belongs to the family of tiger-moths (Arctiidae) and not to the family of tussock moths (Lymantriidae).

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[1] Reference is made by number to "Literature cited," p. 13.

## SYNONYMY.

*Lophocampa caryae* Harris, 1841.
*Halesidota annulifacia* Walker, 1855.
*Phegoptera porphyrea* Herrich-Schäffer, 1855.
*Halisidota caryae* (Harris) Grote, 1882.
*Halisidota caryae* (Harris) *Packard,* 1890.

## DISTRIBUTION.

The hickory tiger-moth is distributed over the northeastern United States and the adjacent Canadian Provinces. According to records of the Bureau of Entomology and literature, its range extends from the Atlantic Ocean west to Missouri, Minnesota, and Saskatchewan, and from the Canadian Provinces bordering the United States south to North Carolina and southern Ohio. Records have been taken from the following States and Canadian Provinces: Maine, New Hampshire, Vermont, Massachusetts, Connecticut, New York, Pennsylvania, New Jersey, North Carolina, Ohio, Michigan, Illinois, Wisconsin, Missouri, Quebec, Ontario, Manitoba, and Saskatchewan. It is probably much more frequent in New England and the Middle States, however, since more than 75 per cent of the reports of destructiveness have come from this region.

## DESCRIPTION OF STAGES.

### EGG.

(Pl. II, fig. 4.)

The egg is nearly globular, flattened on the side of attachment, 0.75 mm. in diameter. The surface is glassy and in color it is a robin's-egg blue when first deposited. A brown ring appears on the upper surface about the second day, and in a few days the egg appears olive brown when viewed from above, although when viewed from the side it is greenish. In about two weeks, just before hatching, it becomes leaden blue. Infertile eggs do not change in color, but dry up in a few weeks. Eggs are deposited in a broad patch of 50 to 400 on the underside of the leaf. The writer has found one patch of 525 eggs.

### LARVA.

(Pl. I, Pl. II, figs. 1, 2, 3.)

*Full-grown larva.*—Length, 32 to 38 mm. A striking grayish-white and black hairy caterpillar. It is covered with short spreading tufts of grayish white hairs, with a dorsal row of contiguous black tufts which appear like a velvety crest. These tufts occur on the first eight abdominal segments and a small one may be seen on the ninth. There also may be a pair of slender black pencils arising from the first abdominal segment, and another pair arising from the seventh. These pencils may be very long, may be inconspicuous, or absent altogether. The head and feet are black. The hair arising from the thoracic segments is longer than that of the rest of the body and when the larva is at rest covers the head. The spreading side tufts give the larva a depressed appearance.

*First instar* (Pl. II, fig. 1).—Width of head, 0.46 to 0.50 mm; total length, 1.5 mm.; when full fed, 3 mm. The head is shining black and is much wider than the thorax of a newly hatched larva. The body is cylindrical, pale greenish white, and marked with black setiferous tubercles. Dorsally the tubercles appear as follows: On the first thoracic segment, a large dorsal plate and two very small tubercles on either side; second thoracic segment, one large compound tubercle on either side near the cephalic margin and a very small median tubercle near the caudal margin; third thoracic segment, 2 conspicuous tubercles on either side; first to eighth abdominal segments, 3 conspicuous tubercles on either side arranged in a triangle, two of them being near the cephalic and one near the caudal margin; ninth abdominal segment, 1 large compound tubercle on each side; tenth abdominal segment, 1 large plate covering most of the dorsal aspect of the segment. On all the thoracic segments and on third to ninth abdominal segments there are 3 small tubercles on each side; on abdominal segments 1 and 2 there are 4 on each side; and on abdominal segment 10 there is 1 one each side. All the lateral tubercles and lateral-dorsal tubercles bear 1 white seta. Black setæ are all dorsal, 4 arising from each thoracic segment, 1 from each of the 4 median abdominal tubercles, and 6 from the anal plate.

*Second instar.*—Width of head, 0.65 mm.; total length, 5 to 6 mm. when full fed. This instar differs chiefly from the preceding in the abundance of long whitish hairs which arise in considerable numbers from all the tubercles. The tubercles are larger and contrast strikingly with the color of the body.

*Third instar.*—Width of head from 1.12 to 1.16 mm.; total length, 10 mm. when full fed. More hairy than the preceding instar.

*Fourth instar* (Pl. II, fig. 2).—Width of head, 1.7 mm.; total length, 13 to 14 mm. The dorsal tubercles are nearly obscured by the hair arising from them.

*Fifth instar.*—Width of head, from 1.88 to 2.19 mm., average 2.1 mm.; total length, 18 to 19 mm. Tufts at sides of each body segment becoming conspicuous, and the black pencils may appear in this instar.

*Sixth instar.*—Width of head, from 2.91 to 3.09 mm., average 3.0 mm.; total length when full fed, 22 to 25 mm. The side tufts have become so conspicuous that they give the larva an almost flattened appearance. The black dorsal tufts are not yet touching and do not yet form a conspicuous crest.

*Seventh instar* (Pl. II, fig. 3).—Width of head, from 3.43 to 3.52 mm., average 3.46 mm.; total length, 27 to 32 mm. Practically the same as the preceding.

*Eighth instar.*—Width of head, from 4.10 to 4.30 mm., average 4.2 mm.; total length, 32 to 40 mm. This larva is very much like the preceding if it has yet to pass through another instar, or if this instar is the last it is like the mature larva previously described.

*Ninth instar* (Pl. I).—Width of head, from 4.7 to 4.9 mm., average 4.8 mm.; total length, 35 to 42 mm. This instar differs conspicuously from the immature forms because of the striking black crest.

## COCOON.

(Pl. III, fig. 3.)

The cocoon is usually ellipsoidal, sometimes slightly flattened on one side, depending on the material which surrounds it. In length it averages 23 mm. and in width 15 mm. The larva mixes most of its gray hairs into the silk, making the cocoon very hairy. In color it is dirty gray.

### PUPA.

(Pl. III, fig. 2.)

Length, 10 to 13 mm; width of thorax, 6 mm; width of abdomen, 7.5 mm. The abdomen is much stouter than the thorax and there is a slight constriction between them; the wingpads extend to the fifth abdominal segment; on the caudal end is a transverse row of spines recurved at the end. Color when newly transformed, yellowish, but soon becoming reddish brown; margins of segments and spiracles darker.

### IMAGO.

(Pl. III, fig. 1.)

The following is Harris's original description of the moth (1):

* * * very light ochre-yellow in color; the fore-wings are long, rather narrow, and almost pointed, are thickly and finely sprinkled with little brown dots, and have two oblique brownish streaks passing backwards from the front edge, with three rows of white semitransparent spots parallel to the outer hind margin; the hind-wings are very thin, semitransparent, and without spots; and the shoulder covers are edged within with light brown. They expand from one inch and seven-eighths to two inches and a quarter or more. The wings are roofed when at rest, the antennæ are long, with a double narrow, feathery edging, in the males and a double row of short, slender teeth on the under-side, in the females; the feelers are longer than in the other Arctians, and not at all hairy; and the tongue is short but spirally curled.

### FOOD PLANTS.

The hickory tiger-moth is usually recorded as a general feeder on the foliage of deciduous trees and shrubs. No less than 49 host plants from widely separated families have been listed by various observers. However, this wide range of food plants is confined to the nearly mature larva. The number of food plants upon which larvæ can develop from egg to pupa is much smaller and, as far as the writer has observed, is restricted to trees of the walnut and hickory family and to pomaceous fruits.

The writer has reared larvæ from egg to pupa on Japanese walnut, English walnut, black walnut, apple, and pear. In the field, colonies have been found frequently on all of the above and also on butternut, quince, and once on white hickory. In spite of its name walnut and not hickory seems to be its favorite food plant. An egg mass was found on a sour-cherry leaf, but a colony of larvæ were never found feeding on cherry in the field. Miss Soule (8) records finding an egg mass on a thorn leaf (*Crataegus* sp.).

The lots of larvæ which were fed on black walnut, Japanese walnut, English walnut, pear, and apple all reached the pupa stage and appeared normal. In the early larva instars the development was about the same. The later instars on Japanese walnut developed somewhat faster than any of the others, and nearly all of them attained the ninth instar before pupation, although those hatching very late passed through only eight instars. Those reared on apple developed more slowly and passed through only eight stages, while the larvæ on pear passed through either eight or nine. The length of stages of larvæ feeding upon these plants will be given in detail in the discussion of seasonal history.

In confinement larvæ would feed on the foliage of many trees upon which they could not mature. Attempts to rear larvæ from hatching to pupation on sour cherry (Early Richmond variety), red oak, and slippery elm were unsuccessful. Those fed on oak and cherry passed through the early molts with regularity, but growth was slower than that of those reared on walnut and apple, and finally stopped altogether. A few larvæ that were started on oak and cherry at the beginning of the second stage reached the seventh, but were undersized and unhealthy in appearance. Elm was more distinctly unfavorable than either oak or cherry. Larvæ placed upon elm immediately after hatching failed to pass even the first molt, and those transferred from walnut as late as the fourth stage failed to pass the seventh.

Table I gives a list of the food plants recorded in entomological literature and in the records of the Bureau of Entomology with the authority for the previously published records. In this list nomenclature of the native species is according to Gray's Manual of Botany, seventh edition (1907), and the nomenclature for imported species is that of Bailey's Standard Cyclopedia of Horticulture.

TABLE I.—*A list of native and imported food plants of the hickory tiger-moth (Halisidota caryae).*

*Acer saccharinum* L. Silver maple. (Beutenmüller 1890.)
*Acer pseudoplatanus* L. Sycamore maple. (Beutenmüller 1890.)
*Acer rubrum* L. Red maple. (Beutenmüller 1890.)
*Acer negundo* L. Boxelder. (Beutenmüller 1890.)
*Acer saccharum* Marsh. Sugar maple. (Beutenmüller 1890.)
*Aesculus glabra.* Welld. Buckeye. (Beutenmüller 1890.)
*Alnus rugosa* (Du Roi). Alder. (Beutenmüller 1890.)
*Betula a.* var. *papyrifera* Marsh. Paper birch. (Beutenmüller 1890.)
*Betula populifolia* Marsh. Gray birch. (Beutenmüller 1890.)
*Carpinus caroliniana* Wall. Hornbeam. (Beutenmüller 1890.)
*Carya* sp. Hickory. (Harris 1841.)
*Carya alba* (I.) White hickory. (Beutenmüller 1890.)
*Carya glabra* (Mill.). (Beutenmüller 1890.)
*Castanea dentata* (Marsh). Chestnut. (Beutenmüller 1890.)
*Celtis occidentalis* L. Hackberry. (Beutenmüller 1890.)
*Crataegus* sp. Thorn. (Soule 1891.)
*Cydonia oblonga* Mill. Quince.[1]

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[1] Confirmed by writer.

*Fagus grandifolia* Ehrh. Beech. (Beutenmüller 1890.)
*Fraxinus* sp. Ash. (Harris 1841.)
*Hamamelis virginica* L. Witch-hazel. (Beutenmüller 1890.)
*Juglans cinerea* L. Butternut.[1] (Fitch 1855.)
*Juglans nigra* L. Black walnut.[1] (Fitch 1855.)
*Juglans regia* L. English walnut.[1]
*Juglans sieboldiana* Maxim. Japanese walnut.[1]
*Larix decidua* Mill. Tamarack. (Fitch, according to Felt, 1905.)
*Larix laricina* (Du Roi). Larch. (Fitch, according to Felt, 1905.)
*Ostrya virginiana* (Mill.). Hop hornbeam.[1]
*Prunus serotina* Ehrh. Black cherry.[1] (Beutenmüller 1890.)
*Prunus virginica* L. Chokecherry. (Beutenmüller 1890.)
*Prunus cerasus*. Sour cherry. (Lintner 1891.)
*Platanus occidentalis* L. Sycamore. (Beutenmüller 1890.)
*Platanus orientalis* L. Sycamore. (Beutenmüller 1890.)
*Pyrus communis* L. Pear.[1] (Lintner 1891.)
*Pyrus malus* L. Apple.[1] (Beutenmüller 1890.)
*Quercus alba* L. White oak. (Beutenmüller 1890.)
*Quercus palustris* Muench. Pin oak. (Beutenmüller 1890.)
*Quercus rubra* L. Red oak. (Beutenmüller 1890.)
*Rhus* sp. Sumach. (Fitch 1855.)
*Rosa* sp.[1]
*Rubus* sp. Raspberry. (Eliot and Soule 1902.)
*Tilia americana* L. Basswood. Beutenmüller 1890.)
*Tilia alba*. White linden. (Beutenmüller 1890.)
*Tilia europea*. European linden. (Beutenmüller 1890.)
*Salix* sp. Willow. (Eliot and Soule 1902.)
*Ulmus* sp. Elm. (Harris 1841.)
*Ulmus americana* L. American elm. (Beutenmüller 1890.)
*Ulmus campestris* L. English elm. (Beutenmüller 1890.)
*Ulmus fulva* Michx. Slippery elm. (Fitch 1855.)

## SEASONAL HISTORY.

### EMERGENCE OF MOTHS.

There is one generation annually. The insect pupates in the fall, hibernates in the pupa stage, and the moths emerge in early summer. During the season of 1916 the earliest emergence from a lot of 36 cocoons was June 9 and the latest June 24, the majority emerging from June 12 to 15, inclusive. No adults were reared in either of the two previous seasons, but in 1914 larvæ were found in the field as early as June 18, indicating that moths must have emerged as early as June 1. In 1915 the larvæ appeared in the field about the same time as in 1916. The data relating to emergence of moths in 1916 are given in Table II.

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[1] Confirmed by writer.

TABLE II.—*Time of emergence of adults of the hickory tiger-moth at North East, Pa., 1916.*

| Date of emergence. | Total number of moths. | Number of males. | Number of females. | Date of emergence. | Total number of moths. | Number of males. | Number of females. |
|---|---|---|---|---|---|---|---|
| June 9 | 1 | 1 | | June 16 | 1 | | 1 |
| 10 | 1 | 1 | | 19 | 1 | | 1 |
| 12 | 4 | 3 | 1 | 22 | 1 | | 1 |
| 13 | 8 | 7 | 1 | 24 | 1 | | 1 |
| 14 | 4 | 3 | 1 | | | | |
| 15 | 3 | 2 | 1 | Total | 25 | 17 | 8 |

### LENGTH OF EGG STAGE.

The length of the egg stage, based on records from 4 egg masses deposited in 1916, was 15 to 16 days. Two masses of eggs deposited June 15 hatched July 1; one mass deposited the same day hatched July 2; the fourth mass, deposited June 16, hatched July 3.

### DURATION OF LARVAL FEEDING PERIOD.

The duration of the larval feeding period varies greatly. Miss Soule (8) records rearing one colony from egg to cocoon in 47 days, which passed through only 7 instars. During the season of 1915 larvæ reared by the writer on Japanese walnut required from 62 to 85 days from egg to cocoon, averaging 74.73 days. (See Table III.)

TABLE III.—*Duration of the larval feeding period, North East, Pa., 1915.*

| Number of individuals. | Duration of larval feeding period. | Number of individuals. | Duration of larval feeding period. | Number of individuals. | Duration of larval feeding period. |
|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* |
| 1 | 62 | 1 | 72 | 2 | 79 |
| 1 | 64 | 2 | 74 | 2 | 80 |
| 1 | 66 | 1 | 75 | 1 | 82 |
| 1 | 68 | 2 | 76 | 1 | 85 |
| 1 | 70 | 1 | 77 | | |
| 1 | 71 | 3 | 78 | 22 | [1] 74.73 |

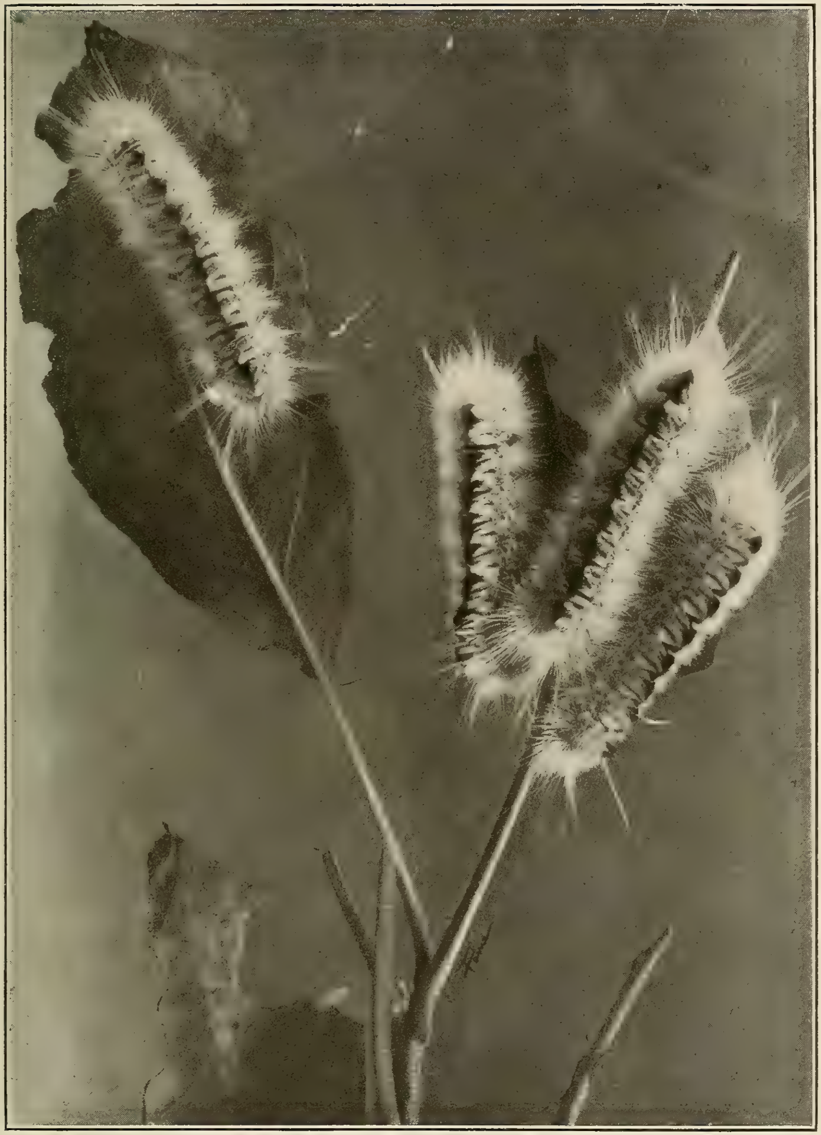
[1] Average.

During the season of 1916 larvæ reared on the same food plant required 80 to 100 days, averaging 89.04 days. (See Table IV.)

TABLE IV.—*Duration of the larval feeding period, North East, Pa., 1916.*

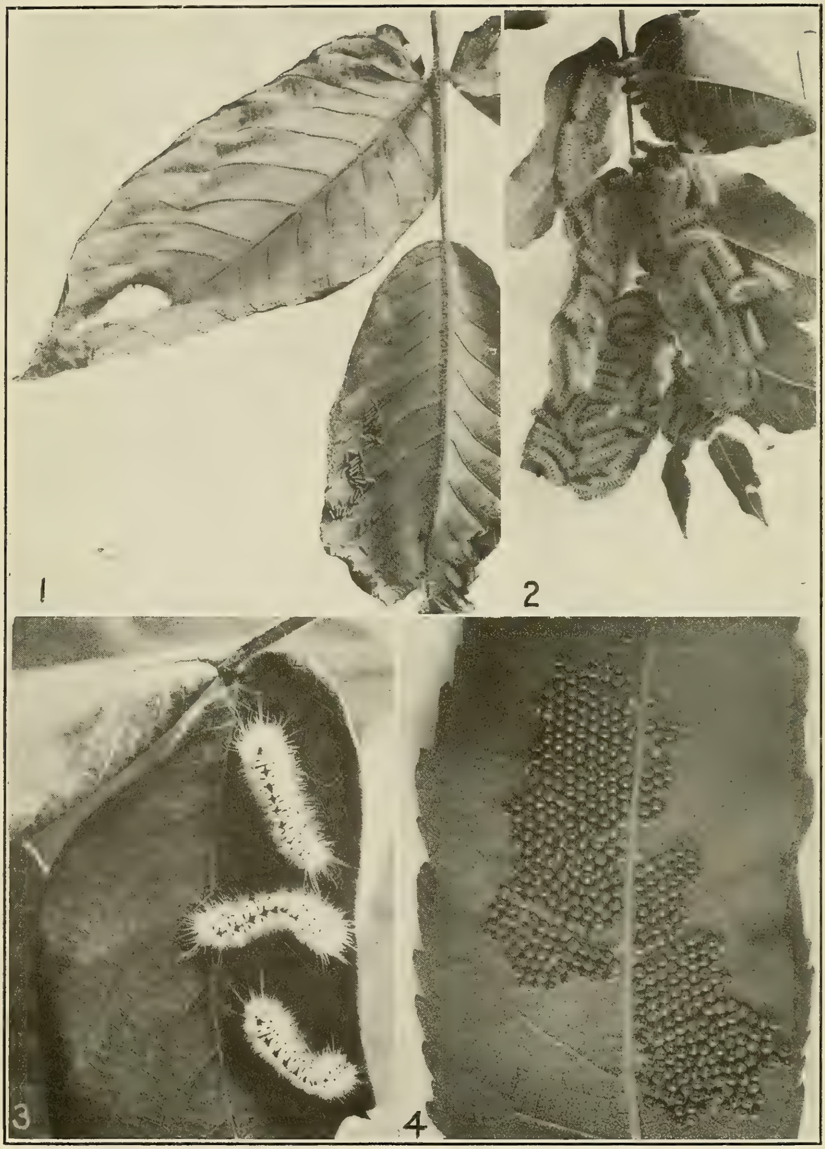
| Number of larvæ. | Duration of larval feeding period. | Number of larvæ. | Duration of larval feeding period. | Number of larvæ. | Duration of larval feeding period. |
|---|---|---|---|---|---|
| | *Days.* | | *Days.* | | *Days.* |
| 3 | 80 | 15 | 88 | 2 | 94 |
| 2 | 82 | 31 | 89 | 2 | 95 |
| 4 | 83 | 26 | 90 | 1 | 96 |
| 9 | 84 | 4 | 91 | 1 | 100 |
| 6 | 85 | 6 | 92 | | |
| 21 | 86 | 8 | 93 | 145 | [1] 89.04 |
| 4 | 87 | | | | |

[1] Average.



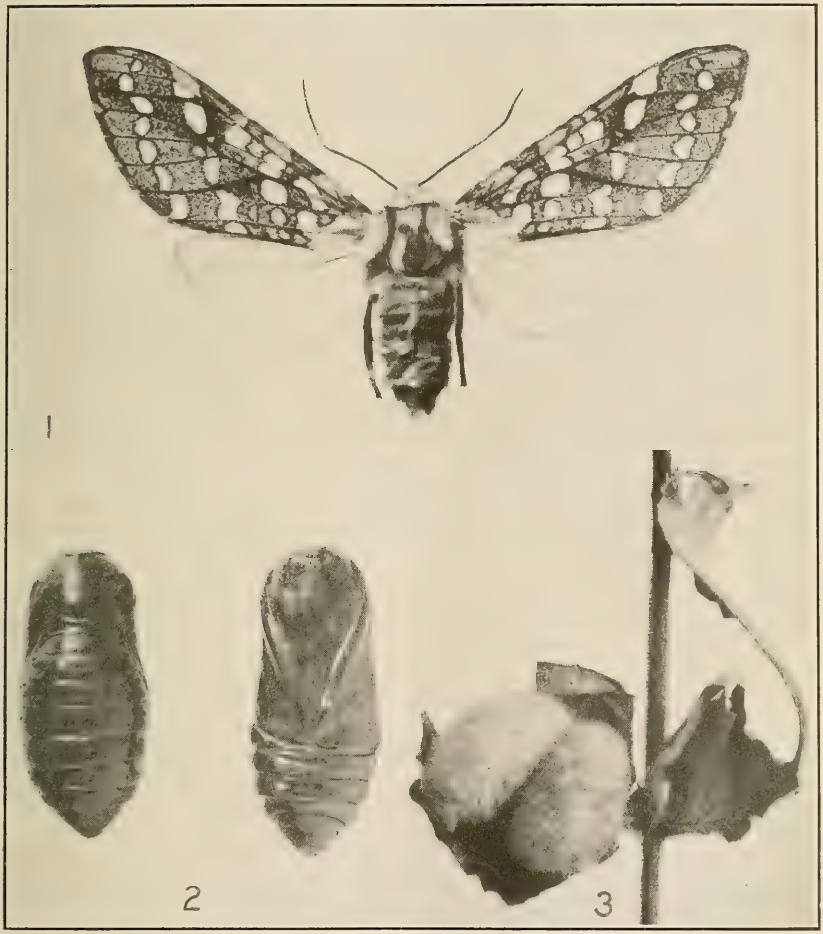
THE HICKORY TIGER-MOTH.

Larvæ on apple leaves, ninth instar. (Original.)



STAGES OF THE HICKORY TIGER-MOTH.

FIG. 1.—Larvæ, first instar. FIG. 2.—Fourth instar. FIG. 3.—Seventh instar. FIG. 4.—Eggs. (Original.)



THE HICKORY TIGER-MOTH AND STAGES.

FIG. 1.—Adult. FIG. 2.—Pupæ. FIG. 3.—Cocoons. (Original.)

The larvæ reared in 1915 passed through only 8 instars, but the majority of those reared in 1916 passed through 9 instars. This could not have affected greatly the time required for development, however, as the few larvæ which passed through only 8 stages in 1916 required an average of 88.71 days. In 1915 the larvæ were reared under natural conditions in bags on a tree, whereas in 1916 all lots but one were reared in battery jars. The one lot of 22 larvæ reared on the tree in 1916 required from 85 to 92 days from egg to cocoon, with an average of 87.18 days, very nearly the same as that of those reared in confinement.

No explanation is offered for the difference in time required for development of larvæ in the two seasons, but it should be stated that the season of 1915 was excessively rainy, whereas the 1916 season was excessively dry. It is probable that humidity affected the rate of development either directly or by its effect upon the food plant.

The duration of the larval feeding period varies somewhat when different food plants are used. The development of those reared on apple was similar to that on walnut, but a little slower, and the larvæ passed through only 8 stages. The shortest period required for development from egg to cocoon was 89 days and the longest was 96 days, with an average of 92.87 days.

Pear seemed a slightly more favorable food plant than apple. The development of the larvæ was more rapid, and although the majority passed through only 8 stages a few passed through 9 stages. Eighteen larvæ which passed through 8 stages required from 87 to 91 days, with an average of 88.77 days; 5 larvæ which passed through 9 stages required from 98 to 100 days, averaging 98.40 days.

The duration of the stages of larvæ reared on Japanese walnut during the season of 1916 was as follows:

*First stage:* Minimum 6 days, maximum 7 days, average 6.12 days; 232 larvæ reared.

*Second stage:* Minimum 4 days, maximum 7 days, average 4.78 days; 232 larvæ reared.

*Third stage:* Minimum 5 days, maximum 7 days, average 5.62 days; 232 larvæ reared.

*Fourth stage:* Minimum 6 days, maximum 7 days, average 6.02 days; 232 larvæ reared.

*Fifth stage:* Minimum 6 days, maximum 8 days, average 6.25 days; 232 larvæ reared.

*Sixth stage:* Minimum 6 days, maximum 13 days, average 8.52 days; 145 larvæ reared.

*Seventh stage:* Minimum 8 days, maximum 20 days, average 12.33 days; 145 larvæ reared.

*Eighth stage* (excluding larvæ that completed their feeding period in this stage): Minimum 13 days, maximum 25 days, average 18.03 days; 138 larvæ reared.

*Eighth feeding stage* (including only larvæ that spun cocoons at end of this instar): Minimum 19 days, maximum 29 days, average 23.29 days; 7 larvæ reared.

*Ninth feeding stage* (until spinning of cocoons): Minimum 13 days, maximum 26 days, average 20.95 days; 138 larvæ reared.

The period covered by the rearing records in 1915 began when the larvæ under observation hatched, on July 17, and continued until time of spinning cocoons, which extended from September 17 to October 10. In 1916 the earliest larvæ hatched June 30, and the first cocoon under observation was spun September 24 and the latest October 10.

### DURATION OF PREPUPA PERIOD.

The larva period in the cocoon at North East, Pa., in 1916 averaged between 7 and 8 days. Of 19 larvæ which spun cocoons on September 24, 25, and 26, 10 pupated in 7 days and 9 in 8 days.

## HABITS.

### THE LARVA.

Larvæ from the same egg mass hatch almost simultaneously and upon hatching eat the greater part of the eggshells. They are gregarious in the early stages, and even in the later stages molt together. During the first four stages they feed gregariously, beginning to scatter in the latter part of the fourth. If during the first three stages a larva is separated from its fellows and is placed on a separate leaf or shoot, it will invariably find its way back to the others within a few hours. When one leaf or shoot is stripped the larvæ move in mass to another, often to another part of the tree.

After the fifth stage the larvæ scatter more or less and are solitary except about molting time. Often they migrate to trees quite a distance from the one on which the colony started. After the last molt the larvæ scatter widely.

The molting of the majority of larvæ from a given egg mass is almost simultaneous, and at this time the gregarious habit is most pronounced. Even after larvæ have scattered over a tree they come together to molt. A short time before molting a silken mat is spun upon which the larvæ rest for about a day before the early molts and sometimes for several days before later ones. This molting mat is spun upon a leaf or bunch of leaves, and sometimes before the later molts on the side of a branch or tree trunk. At each molting period there are often a few larvæ which fall behind and fail to molt with the rest. These invariably develop very slowly and usually do not mature.

Feeding injury is seldom conspicuous and usually unnoticed until the third or fourth instar is reached when the larvæ become very voracious. Larvæ in the first stage are surface feeders. Those on walnut and pear feed on the underside, eating nearly to the upper epidermis. Those on apple and quince feed on the surface. On these food plants the larvæ eat the leaf tissue as they go, while larvæ on cherry and oak leave patches of surface uneaten and also may feed on either upper or lower surface of the leaf. Larvæ in the second stage feeding on walnut and in the third stage on pomaceous fruits feed at the edge of the leaf, eating everything except the thicker leaf veins.

The cocoon is spun among leaves or in protected situations on the ground. If the infested trees are in the neighborhood of buildings cocoons may be found under boards, behind doors, or in similar situations.

### THE PUPA.

The pupa hibernates on the ground. Moisture is probably necessary for successful hibernation, for from 36 cocoons wintered out of doors in a screen basket 25 moths emerged, whereas from 21 cocoons wintered in the insectary in a battery jar and protected from snow and rain, but exposed to the same temperature conditions, none emerged.

### THE MOTH.

In emerging the moth usually breaks the pupal skin and then forces its way out of the end of the cocoon. If the cocoon is very loosely constructed the pupa may break out of it before eclosion, but this is not usual.

Copulation has been noted as early as the day of emergence and oviposition as early as 3 days thereafter. One moth continued ovipositing for 2 days, day and night, apparently without interruption, adding eggs to the same egg mass. Oviposition is performed deliberately. The moth's wings are folded back at rest at this time.

Moths oviposit readily in cages without being fed. They seem to prefer to oviposit on Japanese walnut leaves but will place eggs on cheesecloth or on the sides of the cage. The moths are very sluggish and can be handled easily in cages.

## PARASITES.

This insect is remarkably free from parasitic enemies. None has been reared by the writer, and as far as he is aware only one species, *Pimpla pedalis* Cress (18), has been recorded.

## ECONOMIC IMPORTANCE.

Injury by this insect is intensive and not extensive. It is due to the gregarious larvæ of the early stages which strip branches and sometimes small trees of their foliage. The injury to young trees in particular may be severe. After the gregarious habit is lost the larvæ scatter so widely that the injury done by them is inconspicuous.

Infestation by this insect so far as the writer has observed is not general even within an orchard. Several colonies of larvæ may be on one tree, but the writer has never seen a large tree completely stripped. Usually damage occurs in young orchards on which the codling-moth sprays have not been applied. The increasing importance of the cultivated walnut trees in the northeastern United States probably will cause this pest to become correspondingly more important.

## CONTROL.

Spraying with arsenicals is the usual recommendation for the control of this pest. In orchards which have been thoroughly sprayed for the codling moth the writer has never noted an infestation. Nevertheless, the caterpillar soon becomes very hard to poison, and very large amounts are required to kill it in the later stages.

If control measures are not adopted until the larvæ are in evidence, they probably will not be applied until some of the larvæ are in the third or fourth instar. Spraying at this time is likely to produce discouraging results. Two trees infested with colonies of fourth-stage larvæ were sprayed with arsenate of lead July 31, 1915; on one the poison was applied at the rate of 3 pounds (paste) to 50 gallons and on the other 5 pounds (paste) to 50 gallons. None of the larvæ died until two days later on the tree sprayed with the larger amount of poison, and not until three days later on the tree sprayed with the smaller amount. On the tree sprayed with the smaller amount about 10 per cent of the larvæ survived. It was evident that unless they fed on poisoned leaves continuously for some time they were not affected at all. Unless the larvæ are confined on a sprayed tree they are very likely to migrate to another before eating enough to kill them.

In the gregarious stages colonies of these larvæ are easily collected and destroyed. When the infestation is scattered throughout an orchard this method is much the cheapest that can be employed and is entirely effective.

On young orchards which would not receive the spring spray applications for the codling moth, an application about the last of June of arsenate of lead (paste), 3 pounds to 50 gallons of liquid, would be of value in preventing injury by this pest.

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Fumigation of Apples for San Jose Scale. (Entomology Bulletin 84.) 1909. Price, 20 cents.
Grape Root-worm, with Especial Reference to Investigations in Erie Grape Belt, 1907–1909. (Entomology Bulletin 89.) 1910. Price, 20 cents.
Life History of Codling Moth and Its Control on Pears in California. (Entomology Bulletin 97, Pt. II.) 1911. Price, 10 cents.
Vineyard Spraying Experiments Against Rose-chafer in Lake Erie Valley. (Entomology Bulletin 97, Pt. III.) 1911. Price, 5 cents.
California Peach Borer. (Entomology Bulletin 97, Pt. IV.) 1911. Price, 10 cents.
Notes on Peach and Plum Slug. (Entomology Bulletin 97, Pt. V.) 1911. Price, 5 cents.
Notes on Peach Bud Mite. Enemy of Peach Nursery Stock. (Entomology Bulletin 97, Pt. VI.) 1912. Price, 10 cents.
Grape Scale. (Entomology Bulletin 97, Pt. VII.) 1912. Price, 5 cents.
Plum Curculio. (Entomology Bulletin 103.) 1912. Price, 50 cents.
Life-history Studies on Codling Moth in Michigan. (Entomology Bulletin 115, Pt. I.) 1912. Price, 15 cents.
One-spray Method in Control of Codling Moth and Plum Curculio. (Entomology Bulletin 115, Pt. II.) 1912. Price, 5 cents.
Life History of Codling Moth in Santa Clara Valley of California. (Entomology Bulletin 115, Pt. III.) 1913. Price, 10 cents.
Grape-berry Moth. (Entomology Bulletin 116, Pt. II.) 1912. Price, 15 cents.
Cherry Fruit Sawfly. (Entomology Bulletin 116, Pt. III.) 1913. Price, 5 cents.
Lime-sulphur as Stomach Poison for Insects. (Entomology Bulletin 116, Pt. IV.) 1913. Price, 5 cents.
Fruit-tree Leaf-roller. (Entomology Bulletin 116, Pt. V.) 1913. Price, 10 cents.
Insects Injurious in Cranberry Culture. (Farmers' Bulletin 178.) 1903. Price, 5 cents.
Spraying for Apple Diseases and Codling Moth in the Ozarks. (Farmers' Bulletin 283.) 1907. Price, 5 cents.
Danger of General Spread of Gipsy and Brown-tail Moths Through Imported Nursery Stock. (Farmers' Bulletin 453.) Price, 5 cents.
More Important Insect and Fungous Enemies of Fruit and Foliage of Apple. (Farmers' Bulletin 492.) Price, 5 cents.

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# THE STRIPED PEACH WORM.[1]

By H. G. INGERSON, *Scientific Assistant, Deciduous Fruit Insect Investigations.*

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## INTRODUCTION.

The striped peach worm (*Gelechia confusella* Cham.), although described in 1875, has received little notice as an economic species. The larvæ feed in conspicuous webs on the foliage of the peach and on sand cherry (*Prunus pumila*) in smaller but more compact webs. While at present this insect is not a major pest on peach, the larvæ have been observed feeding on sand cherry in such numbers as to web nearly every terminal, partially defoliating the host plant, and this shows the latent possibility of extensive injury to peach orchards.

Under the direction of Dr. A. L. Quaintance, Entomologist in Charge of Deciduous Fruit Insect Investigations, the writer studied the biology and habits of the insect during the seasons of 1915 and 1916. The biological data secured, together with descriptions of all the stages and suggestions for control, are recorded in this paper.

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[1] The writer is indebted to the following members of the Bureau of Entomology staff: To E. H. Siegler for the photograph used in Plate I, figure 1; to H. K. Plank for Plate II, figure 1, and Plate III, figures 1, 2, and 3; to J. H. Paine for Plate II, figures 2 and 3, and to F. L. Simanton for determining the place of oviposition on sand cherry and for conducting the spraying work in connection with the remedial measures.

The life-history studies were started at Benton Harbor, Mich., in 1915 and completed in 1916.

Adults were reared separately from larvæ collected on the two host plants and were identified as *Gelechia confusella*, by Mr. August Busck, of the Bureau of Entomology.

## HISTORY.

The adult of *Gelechia confusella* was first described by Chambers (1)[1] in 1875, but with no mention of the source of his material. Pettit (4), under the heading "A new peach worm," writes as follows:

> A number of worms working in peach leaves were received from Mr. T. D. Atkinson, of Holland, Mich., on September 17. They were lepidopterous larvæ and were said to be very troublesome. The same species was received on July 3, 1899, from Monroe, Mich. One or two complaints were made from other places, though no specimens were sent.

These are apparently the only published accounts of the occurrence of this insect.

## SYNONYMY.

In 1899 Pettit (4) described the larva of this insect and figured the larva and pupa, designating them "Peach leaf-binder, *Depressaria persicaeella* Murt." In the same publication (5) the adult is described as *Depressaria persicaeella* by Miss Mary E. Murtfeldt, of Kirkwood, Mo., from material sent her by Mr. Pettit. Miss Murtfeldt (6) changes *Depressaria persicaeella* Murt., to Gelechia.

Dyar (7) lists *Gelechia confusella* Cham., with *persicaeella* Murt. as a synonym. Busck (8) lists *Gelechia confusella* Cham. with synonyms *Depressaria persicaeella* Murt. and *Gelechia persicaeella* Murt., and makes the following note:

> Cotypes of Miss Murtfeldt's species are in the United States National Museum under type No. 4697. The species is very close to the foregoing, and I have no doubt is the same as Chambers's *Gelechia confusella*, the type of which is lost but the description of which tallies in every detail with the peach feeder.

In 1904 Pettit (9), under the name "The striped peach-worm (*Gelechia confusella*)," copied part of his former description and reproduced the figures of the larva and pupa of 1899, designating them as the "striped peach-worm." The synonymy stands:

Gelechia confusella Cham., 1875.
    *Depressaria persicaeella* Murt., 1899.
    *Gelechia persicaeella* Murt., 1900.

The writer has accepted the name "striped peach worm," as it seems to distinguish this insect from all other peach feeders and briefly describes the larva, which is the only stage commonly seen.

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[1] Reference is made by number to "Literature cited," p. 14.

## FOOD PLANTS.

Previously published notes have recorded *G. confusella* as feeding only on peach foliage. During July, 1915, the writer observed a webbed condition on sand cherry (*Prunus pumila*) (Pl. IV) which resembled somewhat the injury already noted on peach (Pl. I), though the webs were more tightly bound and less silk was observable. The injury was so extensive and uniform over a sand-cherry thicket of about 15 acres in extent at this place near St. Joseph, Mich., that it seems probable that this is the native host plant of the insect.

## FEEDING HABITS OF THE LARVA.

The larva feed either singly or gregariously on both host plants, and, though not voracious feeders, by their well-developed webbing habit include in their webs much foliage that is not used as food. The larvæ begin webbing directly after hatching, even before they feed, and usually spin the first thin white web on the underside of the leaves next to the midrib. They begin feeding next to the midribs of the leaves, first eating small irregular holes through the parenchyma and later skeletonizing either or both leaf surfaces.

## CHARACTER OF INJURY ON PEACH.

The injury to the peach is caused by the feeding of the larvæ on the foliage. The webs spun by the larvæ are loose, with considerable silk showing, and are often very conspicuous. The leaves soon become dry and cease to function, when included in the webs.

## CHARACTER OF INJURY ON SAND CHERRY.

The webs on the sand cherry are small and compact, with only a little silk showing, but in the fall the infested terminals and branches become prematurely brown and conspicuous. Feeding is confined to the foliage, and, although in rare instances the webs are constructed about fruit, in no cases have larvæ been observed to feed on the fruit. Larvæ of varying sizes are found in the same webs, indicating the probability of repeated oviposition in the same terminal. From 2 to 12 larvæ are usually found in the webs on the separate terminals, although the number is sometimes as high as 30. In most cases observed when there was only one web on a branch it was located at the terminal, but when more than one was present the webs started from the base as well as from the terminal. As the larvæ enlarge the webs, they extend them along the branches, gradually including more and more foliage.

## DESCRIPTION.

### THE ADULT.

(Pl. III, fig. 3.)

Because of its completeness the description of the adult is copied from Murtfeldt:

> Antennæ dark fuscous, indistinctly pectinate and banded on the under side with pale buff. Palpi long, exceeding the vertex. Basal joint short, pale; second joint one-third longer than apical. Brush quite dense, distinctly divided, dark fuscous overlaid with cream-coloured scales, palest on inner side. Apical joint dark, very slender, with extreme tip cream white, most conspicuously so in ♂. Tongue long, sparsely scaled. Vertex dark brown. Face cream white. Thorax and tegulæ purplish-brown. Fore wings almost black, with rich purplish gloss, and sparsely sprinkled with white scales. On the costa back of the apex is a small, irregularly triangular, cream white spot, and a few scattered scales of the same colour form an obscure outer border. In the cell near its upper margin are two somewhat indefinite, cream-coloured dots in line, with a third one below and slightly back of the one nearest the base. Cilia fuscous, shading outward to gray. Lower wings shining silky, cinereous, almost silvery. Abdomen pale brown, terminal segment banded with buff at posterior margin. Lateral tufts buff, inconspicuous; anal tuft reddish-brown. Under surface speckled with brown and cream. Legs brown, annulate with cream white at the joints and middle of the tibiæ. Alar expanse from 16 to 17 mm.

### THE EGG.

(Pl. II, fig. 3.)

The egg is bluntly elliptical, somewhat flattened at the smaller attached end; length, 0.57 mm.; greatest width, 0.42 mm. The color is clear white when newly deposited, changing within 24 hours to a creamy yellow, the surface smooth and shiny without markings. About 24 hours before hatching the eggs change to a pearl gray color.

### THE LARVA.

(Pl. II, fig. 1.)

The newly hatched larva is about 1.5 mm. in length and is yellowish white in color, with head and thoracic shield fuscous. The reddish brown stripes are discernible after about 9 days and as they develop they give color to the larva. A detailed description of the full-grown larva is copied from Pettit:

> The larva, when full grown, is three-eighths of an inch in length and quite slender. Its color is dirty yellowish-white with back and sides marked by six reddish-brown longitudinal stripes all of which extend the entire length from the thoracic shield to the caudal extremity except the pair on the dorsum which unite on the last segment and terminate there. Last segment bordered caudally with fuscous and base of anal pro-legs colored the same. Venter marked along the middle with a stripe like those on dorsum and sides,

which are about equidistant from each other and of about the same width as the spaces between them, color reddish-brown. Some of the spaces (yellowish-white) have dark points in them. Head and thoracic shield yellowish-brown, feet fuscous and dirty yellow. Four pairs of pro-legs beside anal pair which are of the same color as the ground color of the body. Base of anal pair black.

Mature larvæ (Pl. II, fig. 1) were found to vary from three-eighths to five-eighths inch in length, and in color to vary from yellowish white with poorly defined stripes to a clear white with vivid venetian-red stripes. There is an anteriorly directed semicircular black patch over each ocellar area.

### THE PUPA.

(Pl. III, fig. 1.)

The pupa is unusually broad across the thoracic region, slightly flattened dorso-ventrally and quite variable in size. The average dimensions of 10 were found to be 6.3 mm. by 2.6 mm. When newly formed, the pupa is a light brown, changing later to a dark brown, the head, thorax, and ventral region obtaining a much darker color than the other regions. The wing pads are long, extending to cover all but the 3 posterior segments of the abdomen.

### THE COCOON.

(Pl. III, fig. 2.)

This species differs from many of the genus in that it pupates normally in the soil. The larva enters the soil to a depth of about one-half inch and spins a white silken cocoon, which it incloses in fine soil particles and to the outside attaches coarser particles. Within this cocoon the larva pupates. The average size of 38 cocoons measured was 9.3 mm. in length by 4.4 mm. at the greatest width, slightly flattened to conform to the pupæ and usually distinctly curved.

## SEASONAL HISTORY AND HABITS.

The following seasonal-history records were started at Benton Harbor, Mich., during the season of 1915 and were completed in 1916, in open-air insectaries in which glass battery jars were used as rearing cages. In all cases peach foliage was used as food for the larvæ. There is one full brood and a partial second brood.

The rearing studies began with the collection of a quantity of larvæ September 3, 1914. These overwintered, and the moths which emerged were used for part of the 1915 records. The rearing material for 1916 was that kept from the season of 1915, together with moths emerging from pupæ collected in May, 1916.

### EMERGENCE OF SPRING BROOD OF MOTHS, 1916.

The earliest emergence of moths took place on May 22 and beginning on June 5 was quite regular until July 14, with the maximum emergence on June 29.

TABLE I.—*Emergence of spring brood of moths of the striped peach worm in 1916.*

| Date of observation. | Number of moths. | Date of observation. | Number of moths. | Date of observation. | Number of moths. | Date of observation. | Number of moths. |
|---|---|---|---|---|---|---|---|
| May 22 | 1 | June 13 | 12 | June 29 | 60 | July 13 | 3 |
| May 30 | 2 | June 15 | 30 | July 2 | 32 | July 14 | 3 |
| June 5 | 1 | June 17 | 24 | July 4 | 14 | | |
| June 6 | 4 | June 18 | 21 | July 5 | 3 | Total | 364 |
| June 8 | 5 | June 21 | 56 | July 7 | 18 | | |
| June 10 | 6 | June 23 | 43 | July 10 | 4 | | |
| June 11 | 3 | June 25 | 17 | July 12 | 2 | | |

### OVIPOSITION OF SPRING BROOD OF MOTHS.

As the moths emerged they were placed in jars with peach foliage and fruit. The moths oviposited freely in confinement whenever fruit was supplied in the oviposition jars. The eggs were deposited both on the fruit (Pl. II, fig. 2) and under the scales surrounding the attachment of the peach to the stem. In a single instance one egg was found in the axil of a peach leaf. On the sand cherry the eggs were found under the bud scales at the base of the current season's growth and in the axils of the leaves as indicated by the circles shown in Plate IV, figure 1, *a*. The occurrence of the eggs on the peach under orchard conditions was not noted. From Table III it will be seen that in 1915 eggs were being deposited in the jars from June 2 until June 26.

### LENGTH OF LIFE OF MOTHS OF SPRING BROOD.

The length of life of 20 adults which were provided with a weak solution of clarified honey for food is shown in Table II.

TABLE II.—*Length of life of 20 moths of the spring brood of the striped peach worm, 1916.*

| Number of moths. | Days of life. | Number of moths. | Days of life. |
|---|---|---|---|
| 1 | 4 | 3 | 14 |
| 5 | 6 | 1 | 16 |
| 5 | 9 | 1 | 28 |
| 4 | 12 | | |
| | | 20 | |

| | | |
|---|---|---|
| Maximum length of life | days | 28 |
| Minimum length of life | do | 4 |
| Average length of life | do | 10.6 |

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Department of Agriculture, "The Striped
Peach Worm."

## Correction Slip.

Page 11, paragraph immediately following Table X. Second sentence should read as follows: "This late date of feeding is undoubtedly later than would be possible some seasons in the field, for defoliation of peaches sometimes occurs previous to this date, although in the rearing jars the larvae secured the foliage to the twigs by the silken webs in such a way that it could not drop."

The average length of life of the adults is seen to be 10.6 days. From observations made in 1915, however, one adult was found to live 31 days, and eight moths emerging previous to May 24 were alive a month later. These moths were not supplied with food.

### HABITS OF THE MOTHS.

The adults are not often seen in the field because of their small size and inconspicuous coloring. They are difficult to follow when seen because of their habit of short irregular flights and their resemblance when at rest to the color of the twigs of the host plant. The characteristic resting position is shown in Plate III, figure 3, from a photograph of a live specimen. One pair of adults was observed in copulation in a rearing cage on June 21, 1916, at 10.30 a. m. The heads of the male and female were in opposite directions and no parts were in contact except the genital organs. Both moths remained quiet during copulation.

## FIRST BROOD.

### INCUBATION.

In Table III the incubation period for the eggs deposited each day is shown. It will be seen that there was a variation of from 10 to 19 days in the incubation period, and even with eggs deposited the same day on the same fruit and thus subjected to the same external conditions there was a variation of five days. The average length of the incubation period was 13.18 days.

TABLE III.—*Incubation period of first-brood eggs of the striped peach worm at Benton Harbor, Mich., 1915.*

| Date of oviposition. | Number of eggs deposited. | Date of hatching. | Number of larvæ. | Egg stage. | Date of oviposition. | Number of eggs deposited. | Date of hatching. | Number of larvæ. | Egg stage. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | *Days.* | | | | | *Days.* |
| June 2... | 11 | June 15. | 11 | 13 | June 16.. | 6 | June 26.. | 2 | 10 |
| June 3... | 6 | June 16.. | 1 | 13 | | | June 27.. | 2 | 11 |
| | | June 19.. | 2 | 14 | | | June 28.. | 1 | 12 |
| | | June 20.. | 1 | 15 | June 18.. | 29 | June 28.. | 10 | 10 |
| June 5... | 4 | June 21.. | 3 | 16 | | | June 29.. | 13 | 11 |
| June 6... | 28 | June 20.. | 23 | 14 | | | June 30.. | 5 | 12 |
| | | June 23.. | 1 | 17 | | | July 1... | 1 | 13 |
| | | June 24.. | 3 | 18 | June 20.. | 4 | June 30.. | 2 | 10 |
| | | June 25.. | 1 | 19 | June 26.. | 5 | July 7... | 1 | 11 |
| June 10.. | 2 | June 23.. | 2 | 13 | | | | | |
| June 12.. | 20 | June 26.. | 20 | 14 | Total.. | 118 | .......... | 107 | .......... |
| June 12.. | 3 | June 27.. | 2 | 15 | | | | | |

| | | |
|---|---|---|
| Maximum egg stage | days.. | 19 |
| Minimum egg stage | do.... | 10 |
| Average egg stage | do.... | 13.18 |

### Feeding Period of First-Brood Larvæ.

The feeding period of the larvæ in the rearing cages in 1915 extended from June 15 to August 5. In 1916, larvæ were feeding from June 22 until August 1 as shown in Tables IV and V. The longest feeding period recorded was 48 days, the shortest 22 days, and the average 29.6 days for transforming larvæ, and 34.2 days for overwintering larvæ. On July 28, 1915, the writer came upon the injury on sand cherry. The infestation was at its height and practically all the insects in the larva stage. By August 11 about one-half the larvæ had left the webs and newly formed pupæ were to be found in the soil. Observations made on September 14 showed that from 95 to 98 per cent of the larvæ had left the webs.

Table IV.—*Length of feeding period of transforming first-brood larvæ of the striped peach worm, 1916.*

| Date of hatching. | Date of of cocooning. | Number of cocoons. | Days of feeding. | Date of hatching. | Date of cocooning. | Number of cocoons. | Days of feeding. |
|---|---|---|---|---|---|---|---|
| June 22 | July 20 | 1 | 28 | June 25 | July 17 | 2 | 22 |
| Do | July 22 | 3 | 30 | Do | July 20 | 2 | 25 |
| Do | July 24 | 1 | 32 | Do | July 26 | 1 | 31 |
| Do | July 26 | 1 | 34 | | | | |
| Do | July 27 | 2 | 35 | Total | | 14 | |
| Do | July 28 | 1 | 36 | | | | |

Maximum length of feeding period ........ days.. 36
Minimum length of feeding period ........ do.. 22
Average length of feeding period ........ do.. 29.6

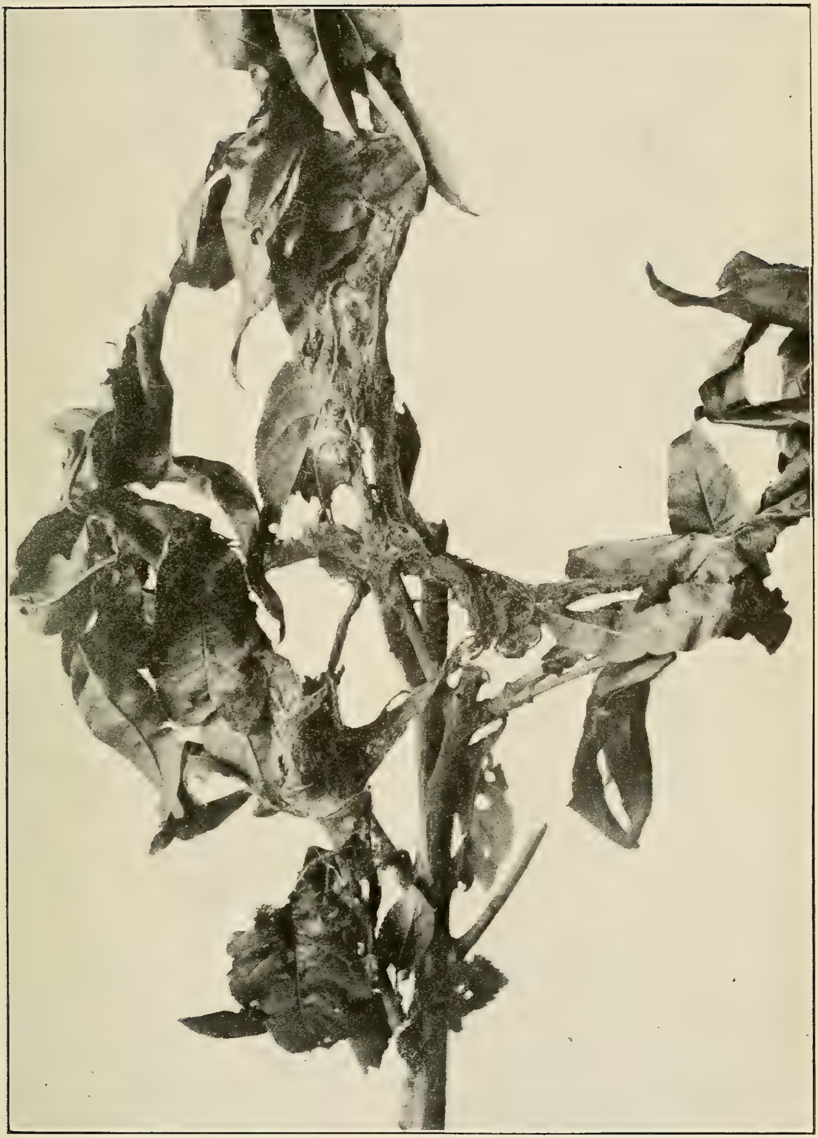
Table V.—*Length of feeding period of wintering first-brood larvæ of the striped peach worm, 1916.*

| Date of hatching. | Date of cocooning. | Number of cocoons. | Days of feeding. | Date of hatching. | Date of cocooning. | Number of cocoons. | Days of feeding. |
|---|---|---|---|---|---|---|---|
| June 22 | July 20 | 2 | 28 | June 22 | Aug. 9 | 1 | 48 |
| Do | July 23 | 1 | 31 | June 25 | July 17 | 1 | 22 |
| Do | July 24 | 2 | 32 | Do | July 26 | 3 | 31 |
| Do | July 27 | 1 | 35 | July 5 | July 31 | 1 | 26 |
| Do | July 28 | 4 | 36 | Do | Aug. 1 | 1 | 27 |
| Do | July 31 | 3 | 39 | | | | |
| Do | July 30 | 2 | 38 | Total | | 23 | |
| Do | Aug. 8 | 1 | 47 | | | | |

Maximum length of feeding period ........ days.. 48
Minimum length of feeding period ........ do.. 22
Average length of feeding period ........ do.. 34.2

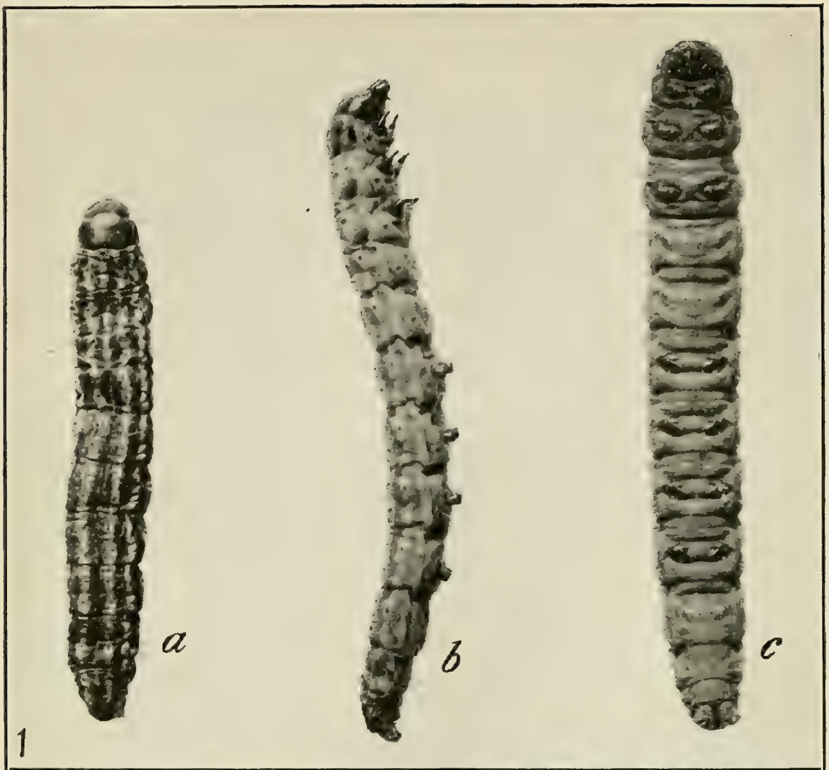
### Cocooning of First Brood.

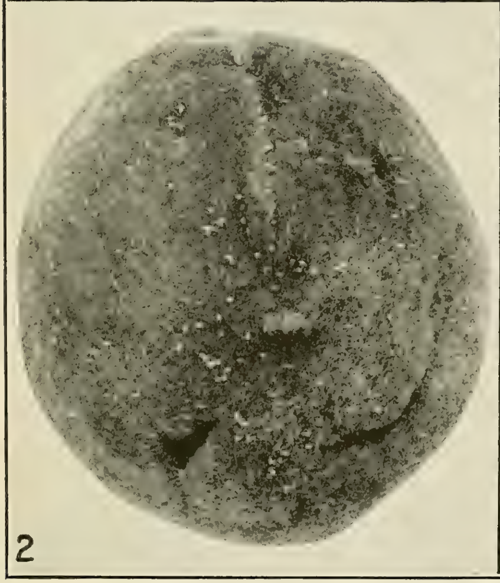
Cocooning takes places in the soil at an average depth of one-half inch, in fine sandy loam in the rearing cages, and this was found to be the usual depth in the soil in the field where the pupæ were found. Of a total of 203 individuals recorded, 31 pupated on the surface of the soil, 154 in the upper half inch, 18 in the second half inch,

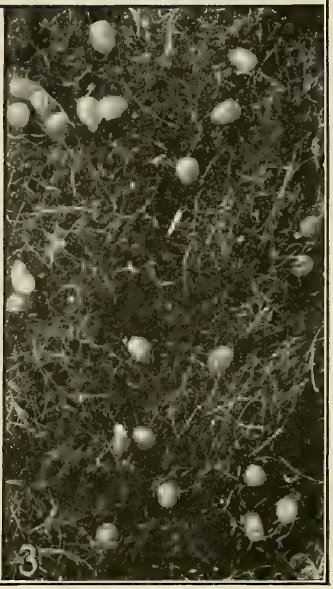


WORK OF THE STRIPED PEACH WORM (GELECHIA CONFUSELLA).

Injury to peach foliage and characteristic webbing. From photograph of limb taken from orchard. About one-half natural size. (Original.)

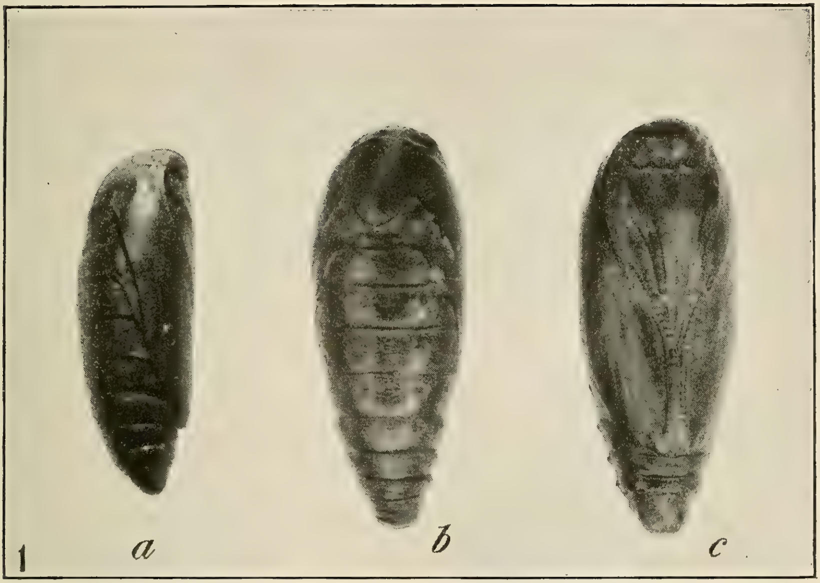


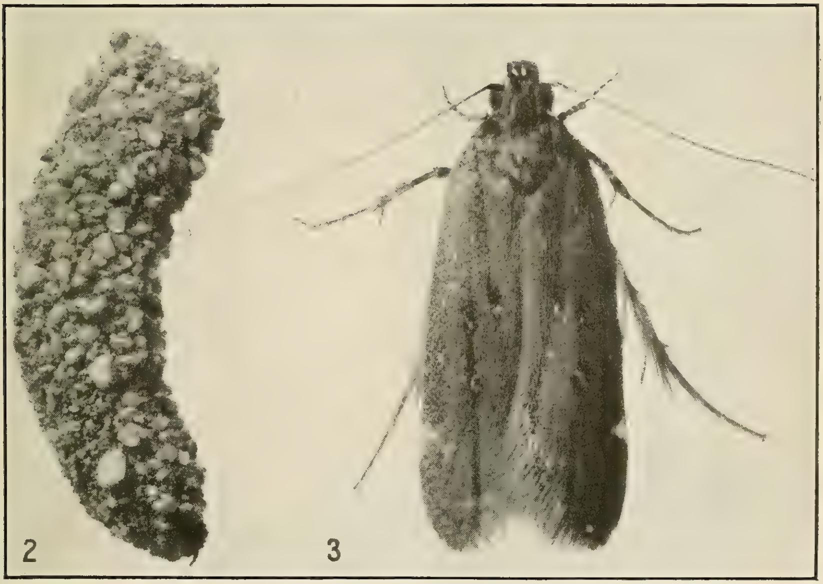




THE STRIPED PEACH WORM (GELECHIA CONFUSELLA).

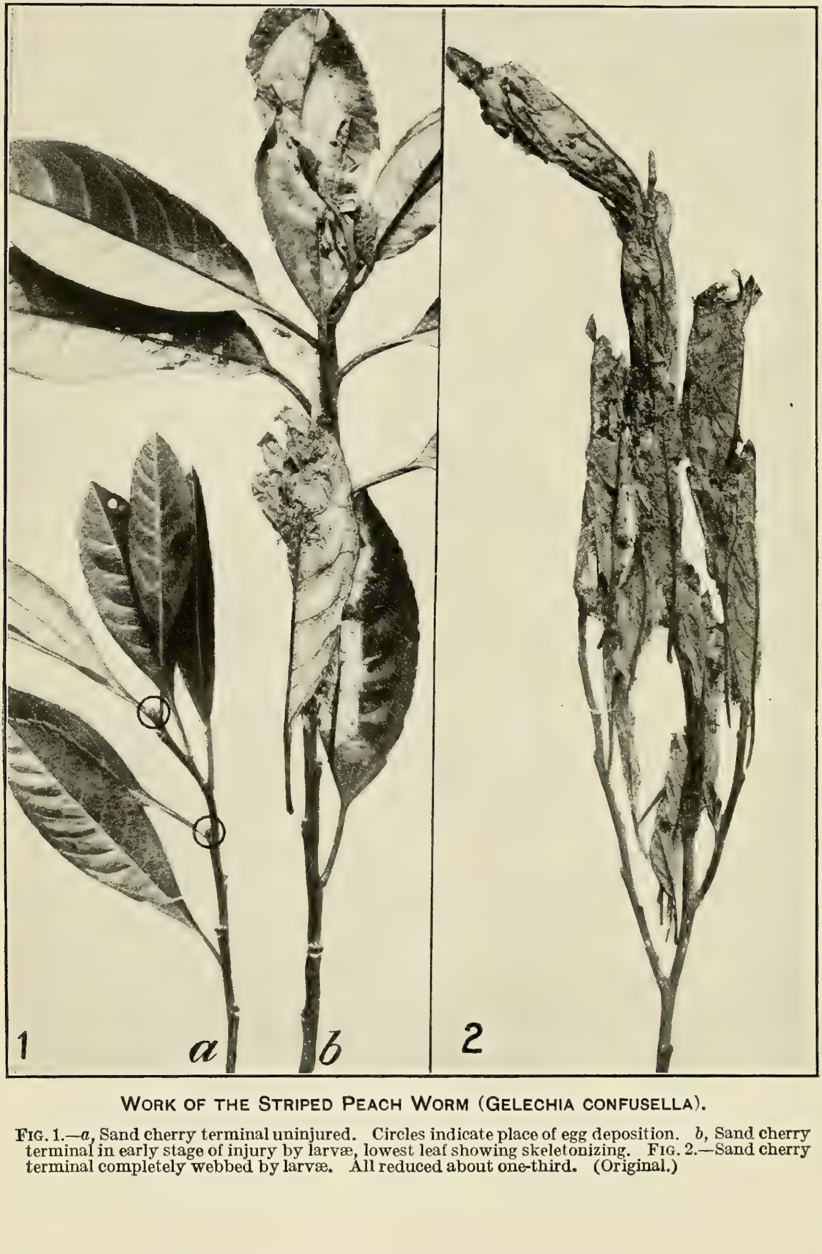
FIG. 1.—Views of larvæ: *a*, Dorsal; *b*, lateral; *c*, ventral. All enlarged about 6 times. FIG. 2.—Eggs on peach, about natural size. FIG. 3.—Eggs enlarged about 11 times. (Original.)





THE STRIPED PEACH WORM (GELECHIA CONFUSELLA).

FIG. 1.—Views of pupæ: *a*, Lateral; *b*, dorsal; *c*, ventral. Enlarged about 9 times. FIG. 2.—Pupal case, enlarged about 10 times. FIG. 3.—Adult, enlarged about 11 times. From photograph of living specimen showing natural position when at rest. (Original.)



WORK OF THE STRIPED PEACH WORM (GELECHIA CONFUSELLA).

FIG. 1.—*a*, Sand cherry terminal uninjured. Circles indicate place of egg deposition. *b*, Sand cherry terminal in early stage of injury by larvæ, lowest leaf showing skeletonizing. FIG. 2.—Sand cherry terminal completely webbed by larvæ. All reduced about one-third. (Original.)

and none deeper. The larvæ in the rearing cages cocooned from July 17 to August 9, but nearly full-grown larvæ collected on sand cherry August 11 were cocooning from August 12 until September 14. The dates of cocooning for the season of 1916 are shown in Tables IV and V, and the length of the period in the cocoon for 17 individuals is shown in Table VI. The average length of the period in the cocoon was determined to be 12.4 days; the longest period, 21 days; and the shortest period, 9 days.

TABLE VI.—*Length of time spent in the cocoon by the first brood of the striped peach worm, 1916.*

| Date of cocooning. | Number of cocoons. | Date of moth emergence. | Days in cocoon. |
|---|---|---|---|
| July 17 | 2 | July 28 | 11 |
| July 20 | 3 | Aug. 1 | 12 |
| July 22 | 2 | Aug. 2 | 11 |
| Do | 1 | Aug. 4 | 13 |
| July 24 | 1 | Aug. 6 | 13 |
| July 25 | 1 | Aug. 4 | 10 |
| July 26 | 2 | do | 9 |
| July 27 | 1 | Aug. 7 | 11 |
| Do | 1 | Aug. 9 | 13 |
| July 28 | 1 | Aug. 18 | 21 |
| Aug. 1 | 1 | do | 17 |
| Aug. 3 | 1 | do | 15 |
| Total | 17 | | |

Maximum length of time in the cocoon .......... days.. 21
Minimum length of time in the cocoon .......... do.. 9
Average length of time in the cocoon .......... do.. 12.4

EMERGENCE OF FIRST-BROOD MOTHS.

TABLE VII.—*Emergence of first-brood moths of the striped peach worm at Benton Harbor, Mich., 1915.*

| Date of emergence. | Number of moths. | |
|---|---|---|
| | *Male.* | *Female.* |
| Aug. 4 | 0 | 4 |
| Aug. 5 | 0 | 1 |
| Aug. 6 | 0 | 3 |
| Aug. 7 | 0 | 4 |
| Aug. 9 | 0 | 3 |
| Aug. 10 | 0 | 9 |
| Aug. 11 | 3 | 1 |
| Aug. 12 | 0 | 2 |
| Aug. 14 | 0 | 1 |
| Aug. 16 | 0 | 3 |
| Aug. 20 | 1 | 0 |
| Aug. 21 | 1 | 0 |
| Aug. 27 | 0 | 2 |
| Aug. 28 | 1 | 1 |
| Aug. 29 | 1 | 0 |
| Sept. 1 | 0 | 2 |
| Sept. 11 | 0 | 1 |
| Sept. 12 | 2 | 3 |
| Total | 9 | 40 |

Table VII shows that first-brood moths were emerging from August 4 until September 12 in 1915, with the largest number on August 10. From 683 larvæ collected on sand cherry July 28 only two moths subsequently emerged that season—one on August 28 and the other on September 9. The dates of emergence of first-brood moths in 1916 are shown in Table VI.

### OVIPOSITION OF FIRST-BROOD MOTHS.

TABLE VIII.—*Oviposition of first-brood moths of the striped peach worm at Benton Harbor, Mich., 1915.*

| Date of oviposition. | Number of eggs. | Date of oviposition. | Number of eggs. |
|---|---|---|---|
| Aug. 15 | 178 | Aug. 18 | 13 |
| Aug. 16 | 26 | Aug. 19 | 10 |
| Aug. 17 | 10 | Total | 237 |

It will be seen from Table VIII that eggs were being deposited from August 15 until August 19, with the greatest number on August 15. The oviposition records are from the moths recorded in Table VII; the late emerging moths failed to oviposit. On the morning of August 19, in transferring a peach on which eggs had been deposited, by mistake one moth was transferred. When the condition of the eggs was observed on the morning of August 23 the moth had deposited 42 eggs in addition to those previously recorded.

## SECOND BROOD.

### INCUBATION PERIOD OF SECOND-BROOD EGGS.

TABLE IX.—*Incubation period of second-brood eggs of the striped peach worm at Benton Harbor, Mich., 1915.*

| Date of oviposition. | Number of eggs. | Date of hatching. | Number of larvæ. | Egg stage. |
|---|---|---|---|---|
| | | | | *Days.* |
| Aug. 16 | 26 | Aug. 31 | 14 | 15 |
| | | Sept. 1 | 2 | 16 |
| | | Sept. 2 | 3 | 17 |
| | | Sept. 3 | 1 | 18 |
| | | Sept. 5 | 4 | 21 |
| Aug. 17 | 11 | Sept. 1 | 5 | 15 |
| Aug. 18 | 13 | Sept. 2 | 8 | 15 |
| | | Sept. 3 | 1 | 16 |
| Aug. 19 | 17 | Sept. 3 | 17 | 15 |
| Total | 67 | | 55 | |

Maximum length of incubation period........days.. 21
Minimum length of incubation period.........do.... 15
Average length of incubation period..........do.... 15.6

In Table IX it will be seen that eggs began to hatch on August 31 and continued to hatch until September 3; the average incubation period being 15.6 days.

### THE EMERGENCE OF THE LARVA FROM THE EGG.

The larva cuts the top of the eggshell with its mandibles and eats the part cut away. By a wriggling movement it forces its head and thoracic legs out of the shell and with these legs on the edge of the shell pushes the rest of the body out by the use of the caudal part of the abdomen. Of four individuals observed, 13 minutes was consumed by each from the first cutting of the eggshell until the larva was entirely free.

### FEEDING PERIOD OF SECOND-BROOD LARVÆ.

TABLE X.—*Length of feeding period of second-brood larvæ of the striped peach worm at Benton Harbor, Mich., 1915.*

| Date of hatching. | Date of cocooning. | Number of cocoons. | Days of feeding. | Date of hatching. | Date of cocooning. | Number of cocoons. | Days of feeding. |
|---|---|---|---|---|---|---|---|
| Aug. 23 | Oct. 7 | 10 | 45 | Sept. 1 | Oct. 24 | 2 | 53 |
| Do | Oct. 9 | 14 | 47 | Do | Oct. 27 | 2 | 56 |
| Do | Oct. 12 | 1 | 50 | Do | Oct. 30 | 1 | 59 |
| Do | Oct. 15 | 1 | 53 | Do | Nov. 2 | 3 | 62 |
| Do | Oct. 24 | 1 | 62 | Do | Nov. 10 | 8 | 70 |
| Do | Oct. 30 | 1 | 68 | Do | Nov. 14 | 2 | 74 |
| Aug. 31 | Oct. 9 | 4 | 39 | Sept. 2 | Oct. 22 | 4 | 50 |
| Do | Oct. 12 | 2 | 42 | Do | Oct. 24 | 1 | 52 |
| Do | Oct. 24 | 11 | 54 | Sept. 3 | Oct. 12 | 1 | 39 |
| Sept. 1 | Oct. 12 | 2 | 41 | Do | Oct. 24 | 1 | 51 |
| Do | Oct. 22 | 8 | 51 | | | | |
| Do | Oct. 15 | 1 | 44 | Total | .......... | 81 | .......... |

Maximum length of feeding period..........days.. 74
Minimum length of feeding period..........do.... 39
Average length of feeding period..........do.... 52.1

Larvæ were feeding from August 23 until November 14, the average length of feeding period being 52.10 days. This late date of feeding is undoubtedly later than would have been possible in the field, for defoliation of peaches occurs previous to this date, although in the rearing jars the larvæ secured the foliage to the twigs by the silken webs in such a way that it could not drop.

### COCOONING OF SECOND-BROOD LARVÆ.

Although cocooning normally takes place in the soil, 13 of 361 individuals recorded pupated in the webbed foliage in which they had lived as larvæ. These pupæ were closely rolled in the individual leaves but not attached to them, and no cocoons were formed. The dates of cocooning are shown in Table X.

## SUMMARY OF SEASONAL-HISTORY STUDIES.

Table XI shows a summary of the seasonal-history studies made on material in rearing cages during the seasons of 1915 and 1916.

TABLE XI.—*Summary of seasonal-history studies of the striped peach worm as observed by rearing during the seasons of 1915 and 1916.*

| Observation. | Season. | Number of individuals. | Number of days. | | |
|---|---|---|---|---|---|
| | | | Average. | Maximum. | Minimum. |
| Length of life of moths of spring brood | 1916 | 20 | 10.6 | 28 | 4 |
| Incubation of eggs of first brood | 1915 | 118 | 13.18 | 19 | 10 |
| Feeding period of transforming larvæ of the first brood. | 1916 | 14 | 29.6 | 36 | 22 |
| Feeding period of wintering larvæ of the first brood | 1916 | 23 | 34.2 | 48 | 22 |
| Length of period in cocoon of first brood | 1916 | 17 | 12.4 | 21 | 9 |
| Incubation of eggs of second brood | 1915 | 55 | 15.6 | 21 | 15 |
| Feeding period of second-brood larvæ | 1915 | 81 | 52.1 | 74 | 39 |

## PARASITES.

While conducting the seasonal-history studies, it was found that the striped peach worm was parasitized by a number of insects. Table XII records the emergence of the Hymenoptera and Diptera which parasitized the 683 larvæ collected on sand cherry July 28, 1915, and 60 pupæ collected in May, 1916.

TABLE XII.—*Emergence of parasites of the striped peach worm (Gelechia confusella), Benton Harbor, Mich., 1915 and 1916.*

| Date of emergence. | Number of parasites. | | Date of emergence. | Number of parasites. | | Date of emergence. | Number of parasites. | |
|---|---|---|---|---|---|---|---|---|
| | Diptera. | Hymenoptera. | | Diptera. | Hymenoptera. | | Diptera. | Hymenoptera. |
| 1915. | | | 1915. | | | 1916. | | |
| Aug. 12 | 0 | 3 | Sept. 2 | 0 | 1 | June 18 | 3 | .......... |
| Aug. 13 | 0 | 3 | Sept. 3 | 1 | 0 | June 23 | 3 | .......... |
| Aug. 14 | 0 | 1 | Sept. 4 | 0 | 1 | June 25 | 1 | .......... |
| Aug. 15 | 0 | 4 | Sept. 10 | 1 | 1 | June 29 | 9 | .......... |
| Aug. 17 | 1 | 1 | Sept. 11 | 0 | 2 | July 2 | 12 | .......... |
| Aug. 18 | 0 | 1 | Sept. 12 | 0 | 4 | July 4 | 9 | .......... |
| Aug. 19 | 0 | 2 | Sept. 14 | 2 | 0 | July 7 | 10 | .......... |
| Aug. 21 | 0 | 2 | Sept. 15 | 0 | 1 | July 10 | 14 | .......... |
| Aug. 22 | 1 | 4 | Sept. 26 | 1 | 0 | July 12 | 2 | .......... |
| Aug. 23 | 0 | 1 | (1) | 0 | 2 | July 13 | 6 | .......... |
| Aug. 25 | 0 | 1 | | | | July 14 | 9 | .......... |
| Aug. 27 | 0 | 1 | 1916. | | | (1) | 17 | .......... |
| Aug. 28 | 0 | 2 | June 11 | 1 | .......... | | | |
| Aug. 29 | 0 | 1 | June 13 | 5 | .......... | Total | 108 | 40 |
| Sept 1 | 0 | 1 | June 15 | 2 | .......... | | | |

[1] No record.

The hymenopterous parasites were identified by Mr. R. A. Cushman, of the Bureau of Entomology. Of 40 specimens submited, the different genera and species were represented as shown in Table XIII.

TABLE XIII.—*Parasites reared from the striped peach worm (Gelechia confusella), Benton Harbor, Mich., 1915 and 1916.*

| Parasite, order and family. | Number of individuals. | Stage of host collected. | Parasite emerged from— |
|---|---|---|---|
| HYMENOPTERA. | | | |
| ICHNEUMONIDAE. | | | |
| *Angitia discoocellellae* Vier | 20 | Larva | Pupa. |
| *Cremastus forbesii* Weed | 1 | do | No record. |
| *Cremastus* sp | 1 | do | Do. |
| *Epiurus indagator* Walsh | 1 | do | Do. |
| BRACONIDAE. | | | |
| *Apanteles gelechiae* Vier | 8 | do | Pupa. |
| *Ascogaster carpocapsae* Vier | 2 | do | No record. |
| *Epirhyssalus atriceps* Ashm. 3 ♂, 4 ♀ | 7 | do | Do. |
| DIPTERA. | | | |
| TACHINIDAE— | | | |
| *Exorista pyste* Walk | 2 | do | Pupa. |
| *Frontina ancilla* Walk | 61 | Larva and pupa | Do. |
| BOMBYLIIDAE— | | | |
| *Anthrax lateralis* Say | 2 | Pupa | Do. |

Bulletin No. 599, United States Department
of Agriculture, "The Striped Peach
Worm."

## Correction Slip.

Page 8, last paragraph, First three lines should read as follows: "Cocooning takes place in the soil. The average depth was one-half inch in fine sandy loam in the rearing cages, and this was found to be the usual depth in the sand where the pupae were found."

The dipterous parasites which emerged in 1915 were identified by Mr. Harrison E. Smith, of the Bureau of Entomology, and those emerging in 1916 were identified by Mr. W. R. Walton, Entomologist in Charge of Cereal and Forage Insect Investigations.

## REMEDIAL MEASURES.

Experiments were conducted in 1916 to determine the efficacy of arsenical sprays in the control of the striped peach worm. Plats were laid out in a sand-cherry thicket and sprayed with arsenicals according to the formulas in Table XIV, all of the adjoining sand cherry serving as checks for comparison.

TABLE XIV.—*Experiments for control of the striped peach worm, Benton Harbor, Mich., 1916.*

| Plat No. | Formula used. | Date of spraying. | Result of spraying. |
|---|---|---|---|
| 1 | Arsenate of lead powder, 1 pound to 50 gallons water. | June 29 | 5 per cent of terminals webbed. |
| 2 | Arsenate of lead powder, 1½ pounds to 50 gallons water. | ...do..... | 3 per cent of terminals webbed. |
| 3 | Check; unsprayed | .......... | 90 per cent of terminals webbed. |

At the time of spraying, a few of the larvæ had hatched and webbed a few terminals. The spray material was applied with a small compressed-air sprayer at a pressure of 70 pounds and sprayed just to the drip. The results of the spraying were very conclusive and both sprayed plats were almost entirely free from infestation when observed on September 19.

### RECOMMENDATIONS.

The occurrence of the striped peach worm may be so local as to permit of the cutting out of the infested terminals or branches, and it will probably not occur in damaging numbers in orchards that are sprayed regularly with arsenicals for control of the plum curculio. Should the infestation be such as to warrant spraying, it is probable that a single application of arsenate of lead paste 2 pounds, or powder 1 pound, to 50 gallons of water to which 2 pounds of freshly slaked lime is added, applied when the first webbing of the leaves appears, will satisfactorily control this insect.

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UNITED STATES DEPARTMENT OF AGRICULTURE
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MILTON WHITNEY, Chief

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# THE RELATION OF SOME OF THE RARER ELEMENTS IN SOILS AND PLANTS.

By W. O. Robinson, L. A. Steinkoenig, and C. F. Miller, *Scientists in Chemical Investigations.*

## CONTENTS.

Introduction — Page 1
Selection and preparation of the samples — 4
Description of the samples — 5
Analytical results — 8
Appendix — 17
  Analytical methods — 17

## INTRODUCTION.

In an earlier publication[1] there were given the results of the examination of a number of important American soil types for the presence of certain of the rarer elements for which reliable methods of analysis had been developed and which it seemed likely might occur in soils.

When this work was completed, it seemed desirable to know whether the rare elements found in soils occurred in plants grown on these soils. If a certain element, though present in minute amounts only, is absorbed by a particular species of plant in relatively large quantities and occurs in other plants in traces only, it would seem reasonable to assume that the element in question has some physiological function. In such cases the element must be in the soil in sufficient quantity or added in the form of fertilizer. There is but little in the literature of plant physiology pertaining to the physiological action of the rarer elements in plant tissues. Frequently when culture experiments have been carried on the elements tested have been found toxic.

Some of the rarer elements very much resemble the commoner ones in chemical reaction. Notable examples are the resemblances of vanadium and phosphorus and of rubidium and potassium.

---

[1] Bul. 122, U. S. Dept. of Agriculture (1914).

In Wolff's tables, which are the only comprehensive compilation of ash analyses, iron and aluminum are seldom differentiated, and the data given for sulphur are known to be too low.[1] For the matter under consideration in this paper these tables are of no value, for rarer elements were not considered.

In the present work the number of elements sought for has been limited by the lack of accurate methods and the improbability of finding certain elements. Titanium, vanadium, chromium, molybdenum, barium, strontium, lithium, rubidium, and caesium have been determined.

Partly for the sake of completeness, and partly because the authors wished to find out if there has been a replacement by a less common but similar element, the commoner elements have also been determined. The data obtained are by no means complete. The variation of the composition of varieties was ignored; the variation of the plant at different periods of growth and the variation in the composition of plants grown on different types of soil are only meagerly covered.

The presence of some of the rarer elements in plants has been previously reported. The references given below include only those elements for which the plants used in this work were examined.

### BARIUM.

Hornberger[2] found 0.97 and 1.20 per cent BaO in two samples of ash from the trunks of copper beeches. He reports the results of earlier investigation in which the presence of barium in beech, oak, birch, and wheat is noted. Crawford[3] supposes the poisonous action of loco weed to be due to barium compounds. There is a comparatively large amount of barium present (0.021 BaO in the dried plant), but Failyer[4] and Alsberg and Black[5] have shown that many other plants, some of which are excellent cattle foods, contain more barium than the loco weed. Alsberg and Black report from 0.006 to 0.030 per cent BaO in various dried plants. McHargue[6] and Artis and Maxwell[7] found barium in tobacco and some other plants. The amount reported varied from 0.010 to 0.128 per cent BaO. Other investigators have reported the presence of barium in plants, but it is not necessary to continue the reference list, since it is well established that barium is a common constituent of plant ash.

---

[1] Hart and Peterson, Wis. Agr. Expt. Sta., Research Bulletin No. 14 (1911). In most cases in Wolff's tables the sulphur was determined in the ash after burning. Skinner, in Bulletin No. 116, Bureau of Chemistry, U. S. Dept. of Agr. (1908), has shown that cottonseed meal and mustard-seed meal lose 90 and 92 per cent, respectively, of their sulphur when ashed.

[2] Land. Vers-Stat., 51, 473 (1899).

[3] Bul. 129, Bureau of Plant Industry, U. S. Dept. of Agr. (1908).

[4] Bul. 72, Bureau of Soils, U. S. Dept. of Agr. (1910).

[5] Bul. 246, Bureau of Plant Industry, U. S. Dept. of Agr. (1912).

[6] J. Am. Chem. Soc., 35, 826 (1913).

[7] Chem. News, 114, 62 (1916).

### CAESIUM.

Von Lippmann[1] found caesium in the ash of the sugar beet.

### CHROMIUM.

The ash of the Scotch fir, silver fir, some vines, poplar, and hornbeam was found by Demarcay[2] to contain spectroscopic traces of chromium. Jorissen[3] found chromium in a sample of coal from Liege. While this may have been originally in plant remains, there is doubt about it, for the same author found chromium in the shales in which the coal was interbedded.

### LITHIUM.

Gaunersdorfer[4] studied the poisoning of plants by lithium salts and found that lithium is a fairly constant but not an essential constituent of some plants.

Tschermak[5] found spectroscopic amounts of lithium in a large number of plants, though in some kinds it did not appear to be present. It appeared more strongly in the leaves and small stems. Voelker[6] found that an application of 200 pounds of $Li_2O$ to the acre was more beneficial than potash fertilization. Contrary to this experience, Ravenna and Zamorani[7] found lithium salts injurious to tobacco and poisonous to beans and oats.

### MOLYBDENUM.

Demarcay[8] reports spectroscopic amounts of molybdenum in vines, fir, oak, hornbeam, and poplar. Jorissen[8] detected it in coal from Liege.

### RUBIDIUM.

Pfeiffer[9] found 1.75 grams rubidium chloride per kilogram of ash from sugar beets. This element was also found in tobacco by the same author. Loew[10] states that small amounts of rubidium chloride gave increased yields of Chinese cabbage, barley, and spinach.

### STRONTIUM.

Haselhoff[11] states that strontium is taken up by plants and appears to replace calcium when there is an insufficient supply of that element. In water-culture experiments larger amounts of strontium salts are poisonous.

---

[1] Ber., 21, 3492 (1888).

[2] Compt. Rend., 130, 91 (1900).

[3] Bul. Sci. Acad. Roy. Belg., 178 (1905).

[4] Landw. Vers.-Stat., 34, 171 (1887).

[5] Zeit. Landw. Versuchsw., 2, 560 (1899).

[6] J. Roy. Agr. Soc., 65, 306 (1904).

[7] Atti. Accad. Lincei. (5), 2, 626 (1909).

[8] Loc. cit.

[9] Arch. Pharm. (2), 150, 97.

[10] Bul. Col. Agr. Tokyo, Imp. Univ., 5, 461 (1903).

[11] Landw. Jahrb., 22, 851 (1893).

### TITANIUM.

According to Salm-Horstmar,[1] titanium may exist in the ash of barley and oats.

### VANADIUM.

Bechi[2] found vanadium in various plants, especially those growing on clay soils. It was present in grasses growing on Etna lava in quantities too small to estimate. Its occurrence in plants is regarded as being due to its ismorphism with phosphoric acid. Coals from Belgium and Peru have been found to contain vanadium. Demarcay[3] detected traces of vanadium in vines, fir, poplar, and hornbeam. Ramirez[4] states that vanadium is absorbed and stored by some plants and causes anomalies in their growth.

### ZIRCONIUM AND RARE EARTHS.

No mention is made of the occurrence of these elements in plant ash. Three plants only were tested for zirconium and the rare earths in this work.

## SELECTION AND PREPARATION OF THE SAMPLES.

So far as it was practicable, the plants selected for this work had grown on soil that previously had been analyzed in these laboratories, and the plant samples were taken as near as possible to the spot where the soil sample had been taken. In selecting plants consideration was given to the fact that there are variations in the composition at different stages of growth and also to the fact that rain water falling on growing plants leaches out no inconsiderable amount of soluble inorganic plant constituents and returns them to the soil. The plants were selected with as much uniformity as possible, the aim being to gather them when in bloom. In all cases, except when otherwise stated, the entire part of the plant above ground was taken for analysis. The majority of the samples were gathered during the latter part of June, 1915. Important crop plants would have been preferred to some of the trees and waste-land grasses, but some soils that had previously been analyzed did not support such crops, so trees and weedlike plants were used. In beginning the investigation it was hoped to study the composition of the same kind of plants grown on soils differing widely in composition; for instance, to compare the lime content of red clover grown on a Hagerstown loam having 0.93 per cent CaO with red clover grown on a York silt loam having 0.08 per cent CaO. No legumes whatever could be found growing on the latter soil, a fact which in itself is significant.

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[1] Johnson, "How Crops Grow," p. 137. New York (1890), Orange Judd Co.

[2] Atti. Accad. Lincei (3) (Mem. Sci. Fis. Mat. e Nat.) 3, 403 (1878–79).

[3] Loc. cit.

[4] Anales. Soc. Quim., Argentina (2), 6, 145 (1914).

The green weights of the samples were not taken. On receipt at the laboratory the samples were air dried at a slightly elevated temperature, ground, and stored in stoppered bottles. The proper grinding of the samples presented many difficulties. An Excelsior coffee mill was found the most efficient machine for the purpose, but the plant fiber in many cases was so tough and leathery that there was always a contamination by the material of the grinder.[1]

For determinations like sulphur, chlorine, and the alkalies, where a small sample was taken for analysis, the material was ground finer in an agate or porcelain mortar.

There was some foreign material in the samples, mostly soil grains adhering to the majority of plants. Nearly all of this material could be removed by brushing and picking, though some of it had to be separated chemically, as described later. The ash of most plants is low in silica, consequently an admixture of even a small quantity of silica from the soil is to be avoided in this case, whereas it would make little difference in ground-rock samples.

## DESCRIPTION OF THE SAMPLES.

### LEGUMES.

1. *Alfalfa.*—One-half mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. This sample was 2 feet high and in bloom when cut.

2. *Alfalfa.*—One mile north of Conshohocken, Pa. Soil, Hagerstown loam. This sample had not bloomed when cut.

3. *Alfalfa.*—Stein farm, Carollton, Mo. Soil type not determined. This sample was mature. It had some fine sand adhering to it so persistently that it was impossible to brush or pick it all off.

4. *Beans.*—String variety. Two and one-half miles northwest of Charlotte, N. C. Soil, Cecil clay. The plants were about 2 feet high and contained blossoms and small pods. There was a heavy rain in the locality just before the plants were gathered, and it was impossible to remove all the soil that had been splashed on the lower leaves.

5. *Beans.*—Seeds of the string variety. Three miles east of Marlboro, N. H. Soil, Gloucester stony loam.

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[1] The iron particles ground off of the machine were very efficiently removed by sliding the sample through a soft iron trough which was in contact with a powerful magnet. As a check on the efficiency of this treatment, the following test was made: A sample of beans (seeds) was coarsely ground, then sampled and analyzed for iron. A subsample was passed several times through the mill, then run over the iron trough and analyzed for iron. A contamination of 5 milligrams $Fe_2O_3$ to 100 grams of bean meal was noticed. Reckoned on the dry basis, this amounts to 0.005 per cent. The grinding of this particular sample was more severe than with ordinary samples, and it can be safely assumed that the contamination of iron in the samples reported was well under 0.005 per cent. In the figures given in the tables no attempt is made to correct for this contamination.

6. *Clover, Crimson.*—Three and one-half miles southwest of Charlotte, N. C. Soil, Cecil sandy loam. This sample was in full bloom.

7. *Clover, Red.*—One-half mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. This sample was in bloom.

8. *Clover, Red.*—One mile northwest of Conshohocken, Pa. Soil, Hagerstown loam. Sample was in bloom.

9. *Clover, Red.*—Three miles east of Marlboro, N. H. Soil, Gloucester stony loam. These plants were mature and the stems frequently carried both blossoms and seeds.

10. *Clover, Sweet.*—One mile northwest of Conshohocken, Pa. Soil, Hagerstown loam. This sample was 4 feet tall, but had not commenced to bloom.

11. *Clover, White.*—One mile northwest of Conshohocken, Pa. Soil, Hagerstown loam. This sample had just commenced to bloom. There was not enough of the sample to complete the analysis.

12. *Clover, White.*—One hundred yards south of derrick, Mount Mica, Paris, Me. Soil type not determined. This sample was gathered about the middle of August when many of the blossoms had seeded. It was not cultivated, but grew in a place formerly occupied by a horse sweep.

13. *Peas, smooth-seeded variety.*—Two and one-half miles northwest of Charlotte, N. C. Cecil clay. This sample contained blossoms and partly matured peas. There was some unavoidable contamination on the lower leaves.

### VEGETABLES AND MISCELLANEOUS CROPS.

14. *Apples, fruit, variety Baldwin.*—Three miles east of Marlboro, N. H. Soil, Gloucester stony loam. It was quite difficult to dry this sample enough to be ground. A moisture determination was made on the partially dried sample, then the whole sample was dried at about 150° C. until it became crisp enough to grind. The total loss in weight was recorded, and a suitable correction applied in calculating the results.

15. *Beets.*—Tubers only. Three miles east of Marlboro, N. H. Soil, Gloucester stony loam. This sample had been stored in a cellar over winter. The small amounts of silica, iron, and aluminum show that there was little soil contamination.

16. *Cabbage.*—Two and one-half miles northwest of Charlotte, N. C. Soil, Cecil clay. This sample was a small head, weighing about a kilogram, and the upper part of the stem.

17. *Carrots.*—Tubers only. Three miles east of Marlboro, N. H. Soil, Gloucester stony loam. This sample was stored in a cellar over winter.

18. *Cotton.*—Plant. Three miles southwest of Laurinburg, N. C. Soil, Norfolk sandy loam. These plants were a little over two feet high and were nearly ready to bloom.

19. *Lettuce.*—One-half mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. This sample was taken after the lettuce had grown tall preparatory to seeding.

20. *Onions.*—Bulbs only. Three miles east of Marlboro, N. H. Soil, Gloucester stony loam. It was impossible to dry this sample to constant weight. After 120 hours of drying at 105° there was still a loss in weight.

21. *Potatoes, Irish.*—Tubers only. Three miles east of Marlboro, N. H. Soil, Gloucester stony loam. Great care was taken to wash the depressions and eyes of the tubers free from soil.

22. *Potatoes, sweet.*—Vines. Three miles southwest of Laurinburg, N. C. Soil, Norfolk sandy loam. These vines were young and had fleshy tips.

23. *Tobacco.*—One and three-fourths miles northeast of Archer, N. C. Soil, Durham sandy loam. The stalks were three and one-half feet high. It had not bloomed.

24. *Tomato.*—Vines. Three miles southwest of Laurinburg, N. C. Soil, Durham sandy loam. The growth was rather small. Flowers and small fruits had formed on the plant.

### GRASSES.

25. *Bluegrass.*—One-eighth mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. The growth was luxuriant. The samples taken were in seed.

26. *Broom sedge.*—Three-fourths mile east of Kings Mountain Battleground, Bethany, S. C. Soil, York silt loam. Small shoots, not in bloom.

27. *Corn.*—Stalks and leaves. Three miles southwest of Laurinburg, N. C. Soil, Norfolk sandy loam. The plants were young and had reached a height of about 4½ feet.

28. *Corn.*—Stalks and leaves. Three-fourths mile east of Kings Mountain Battleground, Bethany, S. C. Soil, York silt loam. The growth was light. The plants were 2 feet high when cut.

29. *Oats.*—Straw with grain. One-half mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. Heavy yield. The grain was in the milk when cut.

30. *Orchard grass.*—One-half mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. These plants had just seeded.

31. *Timothy.*—One-half mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. This sample was cut in bloom.

32. *Timothy.*—One mile northwest of Conshohocken, Pa. Soil, Hagerstown loam. This sample was in bloom.

33. *Timothy.*—Three miles east of Marlboro, N. H. Soil, Gloucester stony loam. Large plants in late bloom.

34. *Timothy.*—One hundred yards southwest of derrick, Mount Mica, Paris, Me. Poor growth, in seed and partly dried.

35. *Wheat.*—Straw with grain. One and three-fourths miles northeast of Archer, Johnson County, N. C. Soil, Durham sandy loam. This sample had made a poor growth.

36. *Wheat.*—Straw with grain. One-half mile west of Penn Square, Norristown, Pa. Soil, Penn silt loam. There was a good yield in the field where this sample was taken.

### TREES AND BUSHES.

37. *Birch, White.*—Leaves only. Beryl Mountain, Acworth, N. H. This bush was growing in a cavity where a large amount of beryl had been taken out. The soil was largely made up of broken beryl. Weight of leaves, 62.9 grams.

38. *Birch, White.*—Stems only. Same locality as above. Weight of stems, 88.6 grams.

39. *Oak, Blackjack.*—Three-fourths mile east of Kings Mountain Battleground, Bethany, S. C. Soil, York silt loam. Entire bush, about 3½ feet high.

40. *Oak, Post.*—Three-fourths mile east of Kings Mountain Battleground, Bethany, S. C. Soil, York silt loam. Entire small tree, about 4 feet high.

41. *Oak, White.*—One and one-fourth mile southeast of Trevilians, Va. Soil, Louisa loam. Entire bush, about 4 feet high.

42. *Oak, White.*—One and three-fourths miles northeast of Archer, Johnson County, N. C. Soil, Durham sandy loam. Small tree, about 5 feet high. Weight of leaves, 124.1 grams.

43. *Oak, White.*—Stems. Location and soil same as No. 42. Weight of stems, 194.5 grams.

44. *Pine, Shortleaf.*—Needles. One and one-fourth miles southeast of Trevilians, Va. Soil, Louisa loam. Weight of needles, 157.1 grams.

45. *Pine, Shortleaf.*—Stems, short. Location and soil same as No. 44. Weight of stems, 134.3 grams.

46. *Pine, Longleaf.*—Needles. One and three-fourths miles northeast of Archer, N. C. Soil, Durham sandy loam. Weight of needles, 273.3 grams.

47. *Pine, Longleaf.*—Stems. As above. Weight of stems, 179.5 grams.

48. *Raspberry* (*wild red*).—Vines. Growing on the edge of a beryl dump on Beryl Mountain, Acworth, N. H.

## ANALYTICAL RESULTS.

The results of analyses of plant ash are given in Tables I to IV, and the analyses of soils on which samples grew in Table V.

TABLE I.—*Results of chemical analyses of plant ash: Legumes.*

[Expressed in per cent of material dried in oven at 105°.]

| Element. | No. 1. Alfalfa. | No. 2. Alfalfa. | No. 3. Alfalfa. | No. 4. Beans (plant). | No. 5. Beans (seeds). | No. 6. Clover. | No. 7. Clover. | No. 8. Clover. | No. 9. Clover. | No. 10. Clover. | No. 11. Clover. | No. 12. Clover. | No. 13. Peas. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| $SiO_2$ | 0.065 | 0.075 | [1]1.50 | [1]0.82 | 0.002 | 0.238 | 0.165 | 0.171 | 0.102 | 0.064 | 0.441 | 0.066 | [1]0.250 |
| $TiO_2$ | .001 | .001 | .011 | .005 | Trace. | .003 | .002 | .002 | .002 | .005 | .002 | Trace. | .008 |
| $Al_2O_3$ | .068 | .007 | [2].306 | [2].215 | .002 | .062 | .023 | .005 | .038 | .009 | .093 | N. F. | [2].201 |
| $Fe_2O_3$ | .039 | .041 | .090 | [2].135 | .012 | .047 | .057 | .070 | .023 | .039 | .083 | .034 | [2].177 |
| MnO | .0071 | .0048 | .0075 | [2].0124 | .002 | .005 | .007 | .0037 | .006 | .0024 | .0046 | .0113 | .008 |
| $Cr_2O_3$ | N. F. | N. F. | N. F. | Trace. | N. F. | N. F. | N. F. | N. F. | .0008 | N. F. | N. F. | Trace. | Trace. |
| $V_2O_5$ | N. F | N. F. | N. F. | Trace. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | Trace. | Trace. | N. F. |
| $MoO_2$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |
| CaO | 2.72 | 2.50 | 2.35 | 2.90 | 1.64 | 1.58 | 2.90 | 2.92 | 2.03 | 1.67 | 2.22 | 1.15 | 1.69 |
| BaO | .008 | .002 | .015 | .019 | .0003 | .012 | .0082 | .006 | .006 | .003 | .0015 | .008 | .007 |
| SrO | .006 | .005 | .023 | .005 | N. F. | N. T. | .014 | N. T. | .004 | .010 | N. T. | .005 | .006 |
| MgO | .715 | .700 | .889 | .670 | .292 | .482 | 1.12 | .785 | .602 | .485 | .720 | .560 | .300 |
| $K_2O$ | 1.46 | 2.53 | 2.92 | 3.65 | 1.71 | 2.85 | 1.59 | 2.38 | 1.84 | 2.45 | N. T. | 4.71 | 3.32 |
| $Na_2O$ | .36 | .26 | .14 | .14 | .01 | .11 | .11 | .10 | .01 | .09 | N. T. | .12 | .20 |
| $Li_2O$ | .000003 | .00001 | .00003 | .00008 | .00003 | .000005 | .00003 | .00002 | .00005 | .000015 | N. T. | .00004 | .00004 |
| $Rb_2O$ | .0018 | .0013 | .005 | Trace. | .0025 | .0006 | .00065 | .0008 | .015 | .00065 | N. T. | .008 | Trace. |
| $Cs_2O$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. T. | N. F. | N. F. |
| $P_2O_5$* | .473 | .861 | .588 | .690 | .990 | .647 | .520 | .566 | .392 | .519 | .709 | .680 | .680 |
| $SO_3$* | 1.01 | .21 | .78 | .76 | .54 | .55 | .48 | .48 | .40 | 1.76 | N. T. | .63 | .83 |
| Cl* | .18 | .35 | .11 | .86 | .07 | .37 | .20 | .20 | .297 | .28 | N. T. | .48 | .83 |
| $H_2O$ at 105° | 7.06 | 10.80 | 8.36 | 8.90 | 10.20 | 6.62 | 8.26 | 7.26 | 9.14 | 6.64 | 7.00 | 8.30 | 9.59 |
| Mineral constituents by addition | 7.1 | 7.5 | 9.7 | 10.9 | 5.3 | 6.9 | 7.2 | 7.7 | 5.7 | 7.3 | .......... | 8.4 | 8.5 |

[1] Some of the silica reported probably comes from fine soil on stems and leaves.

[2] High aluminum and iron content is probably due to unavoidable contamination with soil, the high MnO content of the string beans may be due to the same cause, for the soil contained 0.51 per cent MnO.

* Total $P_2O_5$, $SO_3$, and Cl in plant determined.

TABLE II.—*Results of chemical analyses of plant ash: Vegetables and miscellaneous crops.*

[Expressed in per cent of material dried in oven at 105°.]

| Element. | No. 14. Apples. | No. 15. Beets. | No. 16. Cabbage. | No. 17. Carrots. | No. 18. Cotton. | No. 19. Lettuce. | No. 20.[1] Onions. | No. 21. Potatoes. | No. 22. Potato vines, sweet. | No. 23. Tobacco. | No. 24. Tomato vines. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| $SiO_2$ | 0.012 | 0.014 | 0.184 | 0.015 | 0.290 | 0.538 | 0.011 | 0.008 | 0.410 | 0.125 | 0.519 |
| $TiO_2$ | Trace. | Trace. | .001 | .0002 | .001 | .003 | .0004 | Trace. | Trace. | .001 | .002 |
| $Al_2O_3$ | .006 | .018 | .023 | .012 | .075 | .016 | .006 | .007 | .080 | .062 | .145 |
| $Fe_2O_3$ | .007 | .015 | .027 | .021 | .043 | .117 | .012 | .004 | .048 | .054 | .063 |
| MnO | .0005 | .0067 | .0064 | .0017 | .0123 | .008 | .0030 | .0011 | .0127 | .0123 | .0092 |
| $Cr_2O_3$ | N. F. | Trace. | Trace. | N. F. | Trace. | Trace | N. F. | N. F. | Trace. | N. F. | N. F. |
| $V_2O_5$ | N. F. | Trace. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |
| $MoO_2$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |
| CaO | .056 | .219 | 2.42 | .526 | 4.14 | 3.94 | .393 | .040 | 2.71 | 4.88 | 2.88 |
| BaO | .0003 | .0006 | .003 | .003 | .004 | .008 | .002 | .0006 | .016 | .018 | .008 |
| SrO | .001 | .006 | .012 | .004 | .005 | .036 | .016 | .001 | .007 | .022 | .023 |
| MgO | .067 | .300 | .386 | .310 | .926 | .980 | .209 | .187 | 1.00 | .646 | 1.11 |
| $K_2O$ | 1.00 | 3.93 | 4.41 | 7.22 | 4.06 | 8.66 | 2.04 | 3.29 | 7.45 | 4.57 | 6.85 |
| $Na_2O$ | .01 | .09 | .24 | .43 | .38 | .64 | .20 | .06 | .21 | .39 | .41 |
| $Li_2O$ | .000005 | .000005 | .00002 | .000003 | .00005 | N. T. | .00005 | .000003 | .00005 | .00008 | .000035 |
| $Rb_2O$ | .0013 | .0003 | .0013 | 0009 | .0006 | N. T. | .0009 | .0019 | .0006 | .0038 | .0006 |
| $Cs_2O$ | N. F. | P. | N. F. | N. F. | N. F. | N. T. | N. F. | N. F. | N. F. | N. F. | N. F. |
| $P_2O_5$ | 1.56 | 1.11 | .890 | .800 | 1.19 | 1.30 | .552 | .550 | .920 | .756 | .633 |
| $SO_3$ | .23 | .30 | 2.50 | .38 | 3.53 | 1.14 | .89 | .45 | 1.22 | 1.28 | 4.28 |
| Cl | .03 | .71 | .85 | 1.50 | .16 | 1.40 | .51 | .57 | .24 | 2.50 | .38 |
| $H_2O$ at 105° | 11.64 | 6.40 | 14.74 | 16.85 | 9.30 | 8.73 | .00 * | 9.45 | 9.88 | 14.16 | 7.80 |
| Mineral constituents by addition | 3.0 | 6.7 | 11.9 | 11.2 | 14.8 | 18.7 | 4.8 | 5.1 | 14.3 | 15.3 | 17.3 |

[1] All figures are calculated on the air-dry weight.

TABLE III.—*Results of chemical analyses of plant ash: Grasses.*

[Expressed in per cent of material dried in oven at 105°.]

| Element. | No. 25. Bluegrass. | No. 26. Broom sedge. | No. 27. Corn plant. | No. 28. Corn plant. | No. 29. Oat plant. | No. 30. Orchard grass. | No. 31. Timothy. | No. 32. Timothy. | No. 33. Timothy. | No. 34. Timothy. | No. 35. Wheat plant. | No. 36. Wheat plant. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| $SiO_2$ | 2.72 | 2.28 | 1.10 | 0.99 | 2.10 | 4.40 | 3.19 | 1.58 | 0.784 | 1.29 | 2.17 | 2.50 |
| $TiO_2$ | .002 | Trace. | .003 | .017 | .001 | .0004 | .003 | .002 | .001 | Trace. | .002 | .004 |
| $Al_2O_3$ | .050 | .042 | .030 | .012 | .033 | .048 | .069 | .049 | .041 | .024 | .181 | .173 |
| $Fe_2O_3$ | .025 | .029 | .022 | .037 | .022 | .053 | .041 | .034 | .022 | .038 | .020 | .045 |
| MnO | .0037 | .0157 | .012 | .010 | .0150 | .024 | .005 | .0047 | .008 | .0145 | .0232 | .0061 |
| $Cr_2O_3$ | Trace. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | .004 | N. F. | N. F. | N. F. |
| $V_2O_5$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |
| $MoO_2$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |
| CaO | .264 | .296 | .654 | .660 | .418 | .412 | .369 | .342 | .285 | .270 | .141 | .201 |
| BaO | .004 | .006 | .007 | .002 | .002 | .008 | .004 | .003 | .005 | .002 | .002 | .002 |
| SrO | .002 | .003 | .003 | .007 | .008 | .006 | .001 | .002 | .003 | .002 | .003 | .002 |
| MgO | .191 | .220 | .376 | .420 | .379 | .449 | .243 | .262 | .154 | .110 | .227 | .237 |
| $K_2O$ | 2.49 | 2.04 | 3.37 | 4.22 | 2.65 | 2.97 | 2.50 | 2.11 | 1.97 | 1.90 | 1.26 | 1.02 |
| $Na_2O$ | .02 | .09 | .07 | .13 | .47 | .03 | .01 | .03 | .01 | .10 | .03 | .05 |
| $Li_2O$ | .000075 | .00002 | .00005 | .00005 | .000045 | .0008 | .00002 | .000015 | .00006 | .00001 | .000005 | .000025 |
| $Rb_2O$ | N. F. | N. F. | .001 | Trace. | .0009 | .0006 | N. F. | N. F. | .025 | .01 | .0003 | N. F. |
| $Cs_2O$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | .001 | N. F. | N. F. |
| $P_2O_5$ | .686 | .415 | .593 | .464 | .768 | .591 | .545 | .483 | .395 | .35 | .877 | .602 |
| $SO_3$ | .47 | .38 | .51 | .55 | .71 | 1.01 | .48 | .68 | .22 | .41 | .54 | .33 |
| Cl | .44 | .28 | .19 | .70 | .74 | .52 | .71 | .54 | .50 | .59 | .23 | .31 |
| $H_2O$ at 105° | 9.64 | 7.37 | 13.98 | 12.3 | 8.44 | 10.0 | 7.71 | 9.47 | 7.90 | 9.96 | 10.67 | 8.54 |
| Mineral constituents by addition | 7.3 | 6.1 | 6.9 | 8.2 | 8.3 | 0.5 | 8.1 | 6.1 | 4.4 | 5.1 | 5.7 | 5.5 |

TABLE IV.—*Results of chemical analyses of plant ash: Trees and bushes.*

[Expressed in per cent of material dried in oven at 105°.]

| Element. | No. 37, birch leaves. | No. 38, birch stems. | No. 39, oak. | No. 40, oak. | No. 41, oak. | No. 42, oak leaves. | No. 43, oak stems. | No. 44, pine needles. | No. 45, pine stems. | No. 46, pine needles. | No. 48, pine stems. | No. 48, raspberry vines. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| $SiO_2$ | 0.050 | 0.030 | 0.071 | 0.075 | 0.310 | 0.222 | 0.024 | 0.170 | 0.014 | 0.528 | 0.045 | 0.018 |
| $TiO_2$ | Trace. | N. F. | Trace. | Trace. | N. F. | Trace. | Trace. | .0001 | .0001 | Trace. | Trace. | Trace. |
| $Al_2O_3$ | .024 | N. F. | .033 | .082 | .011 | .038 | .070 | .253 | .090 | .187 | .063 | .077 |
| $Fe_2O_3$ | .029 | .015 | .025 | .024 | .018 | .023 | .020 | .020 | .016 | .021 | .025 | .017 |
| MnO | .0655 | .0098 | .070 | .131 | .049 | .160 | .0393 | .0596 | .011 | .0642 | .0113 | .304 |
| $Cr_2O_3$ | N. F. | N. F. | N. F. | N. F. | N. F. | Trace. | N. F. | Trace. | N. F. | Trace. | N. F. | Trace. |
| $V_2O_5$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | Trace. | N. F. | Trace. | N. F. | N. F. |
| $MoO_2$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |
| CaO | 1.45 | .440 | .95 | 1.36 | 1.85 | 1.14 | 1.25 | .320 | .240 | .434 | .230 | 1.11 |
| BaO | .012 | .005 | .064 | .016 | .012 | .015 | .020 | .005 | .007 | .005 | .006 | .004 |
| SrO | .006 | .004 | .022 | .020 | .004 | .013 | .023 | .003 | .004 | .011 | .004 | .002 |
| MgO | .55 | .170 | .389 | .348 | .300 | .72 | .18 | .210 | .130 | .415 | .129 | .78 |
| $K_2O$ | 1.99 | .58 | 1.55 | .58 | .65 | .91 | .34 | .91 | .30 | .98 | .71 | 1.19 |
| $Na_2O$ | .10 | .13 | .12 | .01 | .11 | .13 | .15 | .07 | .07 | .15 | .13 | .22 |
| $Li_2O$ | .000047 | .00003 | .00006 | .0000065 | .000005 | .00015 | .000003 | .00006 | .0001 | .00002 | .0000065 | .00002 |
| $Rb_2O$ | .001 | .0003 | N. F. | Trace. | .00015 | .000012 | .0015 | .00015 | N. F. | .00063 | .0004 | .01 |
| $Cs_2O$ | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | .001 |
| $P_2O_5$ | 1.10 | .33 | .400 | .146 | .146 | .261 | .274 | .27 | .075 | .221 | .121 | .64 |
| $SO_3$ | .35 | .16 | .30 | .22 | .14 | .35 | .16 | .42 | .14 | .16 | .18 | .13 |
| Cl | .12 | .04 | .04 | .33 | .08 | .06 | .05 | .11 | .05 | .13 | .09 | .12 |
| $H_2O$ | 8.68 | 7.80 | 8.26 | 6.77 | 10.40 | 7.74 | 6.68 | 7.2 | 8.4 | 7.60 | 7.18 | 10.1 |
| Mineral constituents by addition | 5.8 | 1.9 | 4.0 | 3.3 | 3.6 | 4.0 | 2.6 | 2.8 | 1.1 | 3.3 | 1.7 | 4.6 |

TABLE V.—*Showing the chemical composition of certain soils from which plants were gathered.*

[Analyses by W. O. Robinson.]

| Element. | Norfolk sandy loam, 0″–14″, Laurinburg, N. C. | Hagerstown loam, 0″–8″, Conshohocken, Pa. | Gloucester stony loam, 0″–8″, Marlboro, N. H. | Cecil sandy loam, 0″–8″, Charlotte, N. C. | Cecil clay, 0″–6″, Charlotte, N. C. | Durham sandy loam, 0″–10″, Archer, N. C. | York silt loam, 0″–10″, Bethany, S. C. | Louisa loam, 0″–12″, Trevilians, Va. | Penn silt loam, 0″–9″, Norristown, Pa. |
|---|---|---|---|---|---|---|---|---|---|
| | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| $SiO_2$ | 94.50 | 70.99 | 65.68 | 66.49 | 88.57 | 80.79 | 76.71 | 84.58 | 74.33 |
| $TiO_2$ | .71 | 1.01 | .79 | 1.02 | .55 | .55 | .41 | 1.51 | 1.04 |
| $Al_2O_3$ | 2.07 | 11.39 | 14.15 | 17.11 | 5.76 | 10.55 | 12.85 | 5.54 | 11.00 |
| $Fe_2O_3$ | .83 | 4.23 | 5.67 | 7.43 | 1.55 | 1.61 | 2.81 | 3.30 | 4.64 |
| MnO | .007 | .180 | .068 | .51 | .044 | .017 | .005 | .045 | .136 |
| $Cr_2O_3$ | .004 | .004 | Trace. | .013 | .002 | .004 | .007 | .013 | .006 |
| $V_2O_5$ | .01 | .08 | .08 | .05 | .01 | .02 | .04 | .03 | .03 |
| Rare earths | .02 | .08 | N. T. | .02 | .03 | .03 | .02 | .04 | N. T. |
| $ZrO_2$ | .02 | .08 | .04 | .003 | .04 | .08 | .04 | .08 | .05 |
| $MoO_2$ | N. F. | N. F. | N. F. | N. F. | N. F. | P. | P. | N. F. | N. F. |
| NiO+CoO | Doubt. | N. T. | N. T. | .04 | .03 | .04 | N. T. | N. T. | N. T. |
| CuO | N. T. | N. T. | N. T. | P. | P. | P. | N. T. | N. T. | N. T. |
| CaO | .39 | .93 | 1.36 | .36 | .39 | .89 | .08 | .21 | 1.13 |
| BaO | .004 | .060 | .53 | .063 | .039 | .112 | .287 | .037 | .053 |
| SrO | .02 | .11 | .05 | .04 | .01 | .05 | .05 | .04 | .04 |
| MgO | .09 | 1.08 | .83 | .31 | .21 | .19 | .29 | .25 | .69 |
| $K_2O$ | .10 | 2.71 | 2.16 | .62 | .82 | 3.96 | 3.26 | .74 | 1.57 |
| $Na_2O$ | .11 | .82 | 1.39 | .16 | .16 | .87 | .39 | .14 | 1.53 |
| Li | P. | P. | P. | P. | P. | P. | P. | P. | P. |
| Rb | .001 | .002 | .002 | Trace. | .001 | .01 | .001 | .001 | .002 |
| Cs | N. F. | N F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |
| $P_2O_5$ | .06 | .19 | .15 | .17 | .08 | .12 | .05 | .12 | .16 |
| $SO_3$ | .07 | .39 | .17 | .07 | .04 | .06 | .12 | .15 | .15 |
| Ignition loss | 1.74 | 6.08 | 9.52 | 8.06 | 2.93 | 1.41 | 3.16 | 3.89 | 4.51 |
| Water at 110° | .48 | 1.61 | 3.39 | 2.47 | .53 | .48 | .47 | .92 | 1.72 |
| Organic matter | 1.13 | 2.87 | 7.07 | 1.26 | 1.46 | .40 | 1.78 | 2.40 | 1.99 |
| $CO_2$ from carbonates | N. F. | .33 | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. | N. F. |

N. T., not tested. N. F., not found. P., present.

[1] Taken from Bul. 122, Dept. Agriculture (Professional paper).

The results given in these tables are calculated on the moisture-free basis except in cases noted. The total percentage of ash has not been given. It is not practicable to weigh ash on account of its hygroscopic nature, the particles of unburned carbon present, and the variable amount of carbon dioxide present. It is almost impossible to burn to a white ash plants that are high in silica without volatilizing some of the constituents. The silica probably forms a slag with the fluxing alkalies and coats particles of unburned carbon, protecting it from further action.

As an approximation to the total ash the sum of the mineral constituents is given. These figures are comparable to other results given for ash, except that carbon dioxide is not included and that partial correction has been made for the soil grains adhering to the plant. Many published tables show the percentage of a certain constituent in the ash, and the results here published may be compared with such data by taking the sum of the mineral constituents to represent the ash. For example, in Table I, sample No. 1, alfalfa, there is 1.46 per cent of potash in the thoroughly dried plant, and, taking the sum of the mineral constituents to represent the ash, there would be 20.56 per cent of potash in the ash.

Manganese in plants varies more in amount than most of the other elements. It appears to concentrate in the leaves, as shown in the case of the pine and oak samples. The presence of more than 0.3 per cent of MnO in the raspberry plant from Acworth, N. H., is remarkable, and the question arose whether all raspberry bushes and like plants were high in manganese. Two samples, one of raspberry bushes and one of rambler roses from Vienna, Va., were collected and analyzed. The Blackcap raspberry bushes showed 0.062 per cent of MnO, and the rambler roses, stem and leaves, contained 0.019 per cent. This would indicate that members of the rose family contain more manganese than the average of plants. White[1] has found from 0.108 to 0.153 per cent of Mn in sorrel plants, and from 0.059 to 0.085 per cent of Mn in clover plants.

There is wide variation in the composition of the same plant. Some of this variation may be due to the different stages of growth, but the greater part of it would seem to be due to the composition of the soil. For instance, caesium was found in plant ash from Acworth, N. H., and Paris, Me. Caesium beryls are known to occur in both these localities. Shorey[2] reports an extreme variation of the composition of plant ash due to the difference in amounts of lime found in two soils. He writes:

> In the case of the fiber from Sisal Plantation, where the soil was a disintegrated coral, 40 per cent of the ash was lime, while in that from the experi-

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[1] Ann. Rept. Pa. State College Agr. Expt. Sta. (1913–14), p. 46.

[2] Bul. 13, Hawaii Agr. Expt. Sta. (1906).

ment station, where the soil contains less than 1 per cent lime, the amount in the sisal ash was but 7 per cent.

White[1] found considerable variation of the lime content of clover grown in soils of different reaction. The figures are as follows: Alkaline, 3.02 per cent Ca; neutral, 2.68 per cent Ca; and acid; 2.67 per cent Ca.

The attention of the bureau has frequently been called to instances of clovers and alfalfas growing on acid soils. In one such case at Carrollton, Mo., samples of alfalfa were submitted that had been growing luxuriantly on an apparently acid soil for eight years. The growth exceeded that of some alfalfa fields where the soil reaction was apparently more favorable. Mr. J. G. Smith, of this bureau, found the lime requirement of this soil to be 3 tons of CaO to the acre. He also found that the total lime and magnesium in the soil was much higher than the average. An examination of the tables shows that this alfalfa, No. 3, contains somewhat less lime, but more magnesium than the eastern alfalfas. It appears that in this case the alfalfa had extracted the amount of lime and magnesia necessary for normal growth from the calcium and magnesium silicates in the soil and therefore that compounds of these elements are necessary for the elaboration of plant tissue, rather than to give an alkaline reaction to the soil.

There are wide variations in the composition of the same kind of plants, and from the data here presented it can not be stated whether these are due to difference in the stage of growth or to a difference in the composition of the soil. All things considered, however, it would seem that the most profound influence the composition of the soil has on the plant is not on the composition of the plant but on the occurrence of that plant on the soil. To be concrete, it seems that a plant will not grow naturally, seeding itself year after year, on a soil where it can extract only a part of the normal amount of any element necessary for its growth. Diligent search failed to show any legumes, which are high in lime, growing on York silt loam in Bethany, S. C. This soil contains only 0.08 per cent total CaO.

It may be a mere coincidence, but in the majority of cases where the plant contains a comparatively large amount of rare alkalies, there is also an abnormal amount of manganese present. The chlorine of plants that have been cultivated is high, particularly those that are usually fertilized with commercial fertilizer. Such large amounts of chlorine may not be necessary for the elaboration of plant tissue, but it seems that chlorine and sulphuric acid act as necessary vehicles to carry the alkalies from the soil to the plant. In the cotton plant, lettuce, and tobacco plant, where the potash and lime are abnormally high, the sum of the sulphur and chlorine is also high.

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[1] Ann. Rept. Pa. State College Agr. Expt. Sta., 1913–14, p. 46.

Vernadsky[1] has shown that rubidium and caesium are widely distributed in feldspar and micas and consequently in soils. He is of the opinion that these alkalies may occur in sufficient quantities in agricultural products to affect the accuracy of potassium determinations. In so far as plants are concerned, the contention of Vernadsky does not seem to be well founded, for there were only three cases where the quantity of rubidium was large enough to be detected in the potassium determinations, and in those cases the amount of potassium would be increased by about 0.01 per cent.

The aluminum in plants varies widely. In some cases there is more aluminum than iron. It is true that a large number of errors accumulated upon this determination, but every precaution was taken to correct for impurities, and it is believed that the results are not consistently too high. Unavoidable contamination by soil would, of course, result in a figure for aluminum higher than the true one. Such contamination would be shown by a correspondingly high silica content. High results for aluminum were checked by another analyst.

The results with reference to the rarer elements may be summarized as follows:

1. Lithium was found in spectroscopic quantities in all plants examined. Rubidium was present in the majority of cases and in larger quantities than the other rare alkalies. In cases where the amount of $Rb_2O$ in the plant equaled or exceeded 0.01 per cent, rare alkali minerals are known to occur in the soil on which the plant was grown. Caesium was found in the ash of timothy from Mount Mica, Paris, Me., the red raspberry from Beryl Mountain, Acworth, N. H., and the beets from Marlboro, N. H. Caesium beryls are known to occur in the first two localities.

2. Chromium was occasionally found, though always in very small amounts. Vanadium was detected in only six instances and likewise in traces. Molybdenum was not found by delicate chemical tests in the ash of any plant.

3. Barium was found in determinable quantities in the ash of all plants examined. Strontium was found in all samples except bean seeds.

4. Titanium was present in the ash of all plants, though in very small amounts. With two exceptions, all plants analyzed contained aluminum. The percentages of aluminum in peas, beans, one sample of alfalfa, pine needles, wheat, and tomato plants are high. The peas, beans, and alfalfa were contaminated by soil to which the high

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[1] Ueber die Begleiter des Kaliums.

aluminum content probably is due. Pine needles are exceptionally high in this element.

5. There is no evidence that vanadium replaces phosphoric acid in its functions in the plant. Rubidium and caesium are apparently absorbed by the plant when they are present in the soil solution. The larger the amount present in the soil, the more will be absorbed. Lithium is apparently not acted on in this manner, for Nos. 12 and 34 did not contain an exceptional amount of lithium, though the soil contained considerable lepidolite.

6. With the exception of sulphur, chlorine, and manganese in some cases, there is no indication that the elements determined in the foregoing work, except those commonly used, need be considered in fertilizer practices.

## APPENDIX.

### ANALYTICAL METHODS.

Since this work is based largely on analytical data, it seems proper that the methods employed should be stated with some detail. No satisfactory method for the complete analysis of plant ash is to be found in textbooks or bulletins. The problem is one of peculiar difficulty. The inorganic composition of plants nearly resembles that of a rock phosphate, except that there is a high content of magnesium, more iron and aluminum, and occasionally large amounts of manganese. Obviously some method which would remove the phosphoric acid early in the analysis and leave no objectionable precipitant in solution would be the ideal procedure. The basic acetate method for the precipitation of the iron group had to be discarded on account of the tendency of the small amount of iron and aluminum phosphate to run through the filter.

Treadwell and Hall have outlined a method whereby the phosphoric acid is precipitated with molybdic acid in the usual manner and the iron and aluminum separated by ammonia and ammonium sulphide, which does not precipitate the molybdenum. Test analyses made on synthetic solutions showed that iron and aluminum were not completely precipitated by this treatment, and the method was abandoned as unsatisfactory.

The phosphoric acid may be removed by silver salts in slightly acid solutions, but the coprecipitation of iron renders this separation useless.

The stannic acid made by dissolving tin in a nitric-acid solution containing a phosphate will precipitate the phosphoric acid as tin phosphate, and no tin remains in solution. Unfortunately, iron is precipitated with the tin, so the method could not be used.

After a number of trials it became evident that the method which calls for the separation of calcium as sulphate by alcohol, after the removal of silica, was the best available. Test analyses by two analysts on synthetic mixtures showed this method to be accurate. It is outlined in Mellor's, "A Treatise on Quantitative Inorganic Analysis," p. 606, J. B. Lippincott Co., Philadelphia (1913).

This method was found satisfactory after modification; that is, the removal of the iron precipitated with the calcium sulphate and the recovery of magnesium from the iron group after the precipitation of phosphoric acid, by the use of citric acid and ammonium phosphate.

## SILICA.

It is impossible to prepare plants for analysis in such a manner as to have them free from contaminating soil, which is made up largely of silica. An approximate way of determining silica is carried out by digesting the dehydrated silica and sand with a solution of sodium carbonate and hydroxide as outlined in Bul. 107, of the Bureau of Chemistry. The finely divided silica of constitution dissolves, and the soil grains are supposed to resist attack. It is difficult to obtain results by this method which agree well, particularly when working with plants high in silica. For the separation of silica, two evaporations with an intervening filtration were invariably made.

## THE CALCIUM PRECIPITATION.

The calcium sulphate precipitated by alcohol frequently contains iron but never phosphorus, provided, of course, the washing has been thorough. It has been our practice to dissolve the calcium sulphate in hydrochloric acid and precipitate the iron, if any, with ammonia and add it to the main precipitate. When the final volume of the alcoholic solution in which the calcium-sulphate precipitation was made is from 150 c. c. to 200 c. c. from one to two milligrams of calcium sulphate remain in solution. This was shown by the test analysis of synthetic test solutions.

## THE IRON AND ALUMINUM GROUP.

The skill of the analyst is put to a severer test in making this group separation than at any other stage of the analysis. The precipitation must be quickly and completely made and the filtration hastened with all possible dispatch. This is to avoid the coprecipitation of magnesium phosphate. To this end a small but known excess of ammonia is quickly added to the hot mixture. The solution is then boiled a minute or so and the filtration made by suction in a hot-water jacketed funnel. If there is not too much magnesium present these precautions will enable the analyst to obtain a precipitate free from magnesium or nearly so. The presence of magnesium ammonium phosphate in the iron group can easily be recognized by the appearance of crystals on the side of the beaker. When such precipitate appears it is best to complete the filtration and make a second precipitation. In this way the amount of magnesium is so reduced that it will seldom give further trouble. The washing is best done with hot water containing 5 per cent $NH_4Cl$. After complete washing water containing $NH_4NO_3$ is used to wash out the chloride prior to ignition. Some electrolyte must be used in the wash water, otherwise the phosphates of iron and aluminum will run through the filter.

Correction for the magnesium which may be in the iron group was made in the following manner: After the titanium has been determined and the phosphoric acid precipitated 1 to 2 grams of citric acid are added to the solution and the magnesium precipitated with an orthophosphate and ammonia. A correct figure for aluminum can be certain only after this magnesium correction has been made. In cases where the manganese is below or only slightly above 0.01 per cent none will be found precipitated with the iron group, nor is it necessary to correct the magnesium precipitate for such an insignificant amount. When the manganese is high, as in the raspberries, pine needles, and oak leaves, corrections are necessary. A simple colorimetric determination of the manganese in the magnesium pyrophosphate gives data enabling the analyst to give a correct figure for magnesium. Correction is made for the aluminum in the following manner: The solution of the iron group, after the titanium has been determined and the phosphoric acid has been removed, is divided into two portions; in one the manganese is estimated colorimetrically and the magnesium correction is made in the other half.

The precipitation of the magnesium and phosphoric acid in the separate halves of the filtrate from the iron group is done in the ordinary manner.

### THE ALKALIES.

Great care must be used in ashing the plants, particularly when the rare, more volatile alkalies are to be determined. Potash is lost when present as the chloride, if the temperature of ignition be carried above a dull redness, barely discernable in the dark. In order to control this temperature of ignition, a special electric muffle was constructed. When the temperature, as measured by a pyrometer on the inside of the furnace and not touching the walls, did not exceed 525° C., there was no loss of potash during ashing. This fact was established by comparing analyses of the same plant made using and omitting sulphuric acid during the ignition. In this laboratory, where the voltage of the electric current varies considerably, the very frequent attention of the analyst is required to operate the rheostat of the electric furnace in order to keep the temperature approximately uniform. The difference in radiation from the furnace on hot and cold days is another factor which causes variation in temperature when the rheostat is set at the same place. To secure a fairly constant temperature without the element of guesswork, a furnace with a temperature regulator was designed. A sketch is given in figs. 1, 2, and 3.

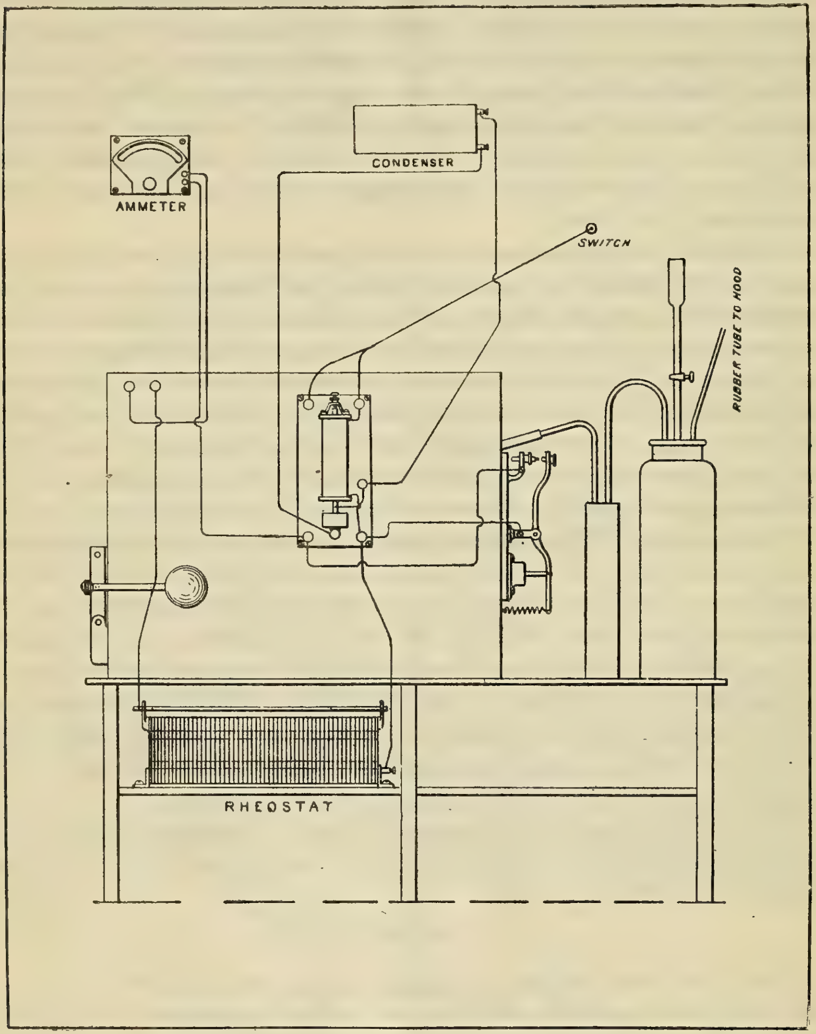

FIG. 1.—Diagram of electric furnace, side view.

The essential part of the automatic control is a couple consisting of a quartz tube closed at one end, inside of which is placed a nickel rod. The difference in the thermal expansion of nickel and silica is

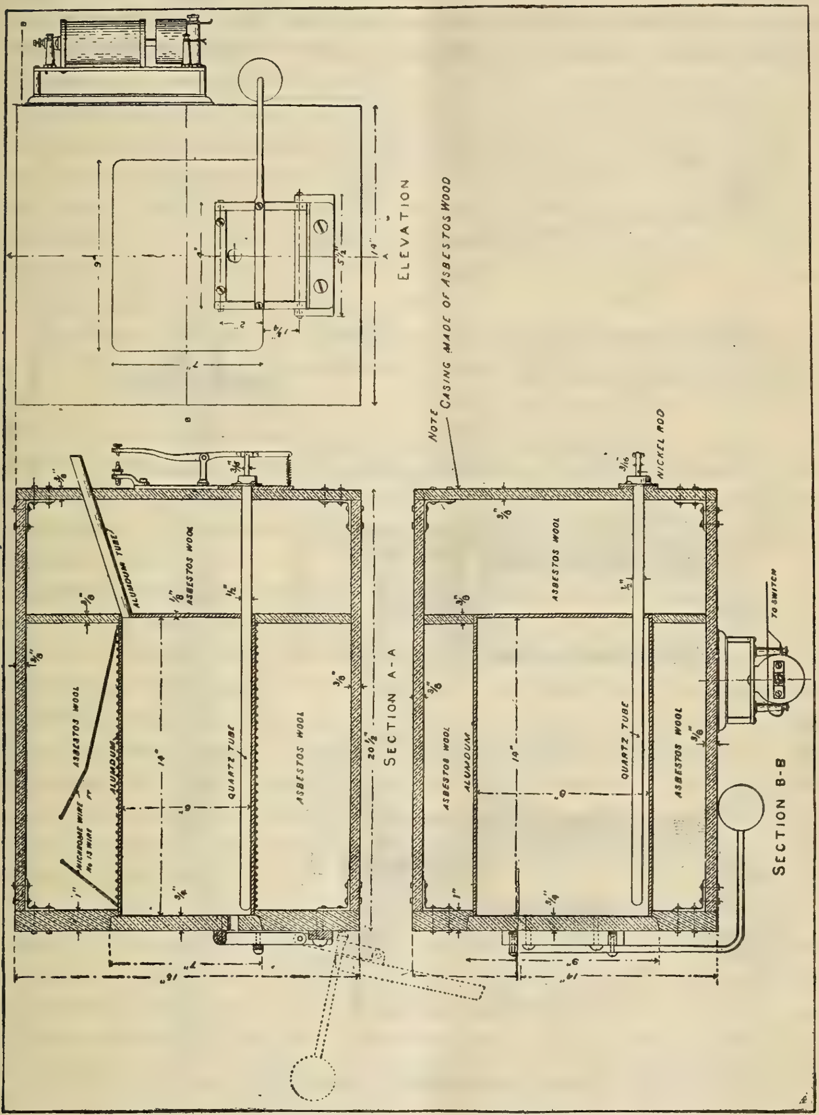

FIG. 2.—Sectional view of electric furnace.

considerable. By this device a movement of 0.01 inch for every 2½° C. was obtained. No change in temperature of the oven running at 525° C. could by observed with a pyrometer graduated in 5-degree intervals.

## THE ELECTRIC FURNACE.

The inner case of the furnace is made of alundum on which is wound nichrome wire of 0.072-inch diameter. The resistance of the furnace is 12 ohms. At the rear an alundum tube is inserted to lead off the volatile matter to a cooling cylinder of metal which is connected to a bottle containing water and small pieces of pumice. The other opening of the bottle is connected with the suction. Asbestos wool forms the insulating material between the alundum case and the asbestos-board outer form. The door of the furnace is mounted with double hinge and weighted to remain open or closed, as placed.

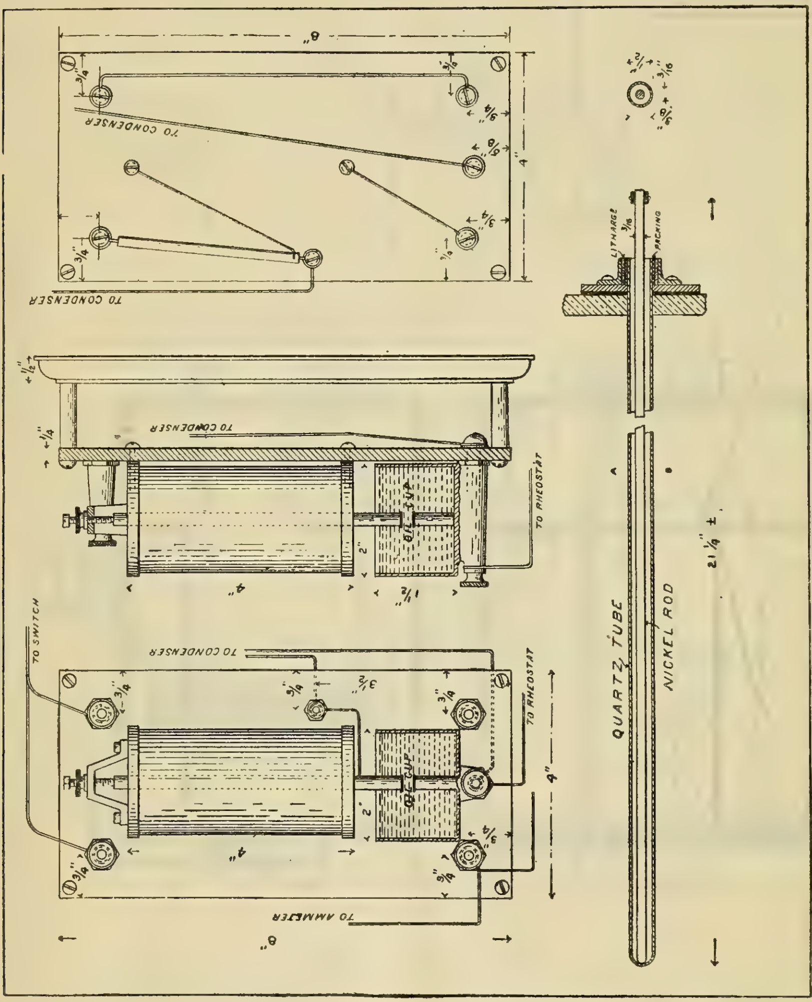

FIG. 3.—Details of regulating devices.

The temperature of the furnace is controlled through the action of the nickel rod which is placed inside a quartz tube. The quartz tube was fastened at the rear of the furnace to the inside of a brass piece by means of glycerine and litharge cement, after the end of the tube had been wound with asbestos cord. The other end of the lever connected with the nickel rod makes and breaks the current operating the relay. A condenser is connected with opposite sides of the gap to reduce arcing. The platinum-tipped contact pieces are also immersed in oil, which further reduces arcing tendencies. An ammeter and rheostat are connected in series with the furnace. When started with a current of 12 amperes (at 220 volts) the furnace requires about an hour and a half to reach a temperature of 500° C., after which the temperature may be kept constant with a current of 7 amperes, which is easily handled by the relay.

The time required for ashing of different plants varies considerably. Three hours is generally sufficient. The contents of the ashing dish were turned to expose unburned portions when necessary. Many times one incineration was sufficient for complete ashing, but generally all plants high in silica required a second heat treatment after leaching with water. The silica apparently forms a slag with the alkalies and protects enmeshed particles of carbon from the action of the oxygen.

It was found more convenient to determine the sodium and potassium in the same portion that was taken for the major constituents. The ash was dissolved in hydrochloric acid, with repetition of the ignition and extraction of the residue if any, and the filtrate made up to definite volume. An aliquot corresponding to 1 or 2 grams was taken for the alkalies. This was evaporated to dryness to free from the excess of acid. Clear barium hydroxide solution was added in slight excess and the solution filtered. All interfering elements are eliminated by this process, and from this point on the ordinary procedure is followed.

For lithium, caesium, and rubidium 20 grams of the dry plant were taken. This amount was carefully ashed, the ash dissolved in hydrochloric acid, and the excess of acid evaporated off. The magnesium, phosphoric acid, etc., were precipitated by lime, the lithium and sodium separated from the other alkalies by platinum-chloride, and the caesium and rubidium fractionated from the potassium in the same manner as outlined in Bulletin No. 122 of the United States Department of Agriculture. The determinations were made spectroscopically according to the method of Gooch and Phinney[1] with a Hilger wave-length spectroscope. Lithium was identified by the line 6708.2 and caesium and rubidium by the doublets 4593.3—4555.4 and 4215.6—4201.9, respectively.

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[1] Am. J. Sci., 44, 392 (1892).

### MANGANESE.

It was first hoped to make the manganese determination in the same subsample as that used for the determinations of barium, chromium, vanadium, and molybdenum. After the ash is fused with sodium carbonate it seems possible to precipitate the manganese with alcohol or hydrogen peroxide and determine the manganese in the insoluble portion, but while this method gives good results in many cases occasionally large errors were found. Using the Weller method the color seems to develop quicker and more uniformly when all the constituents of the plant ash are present, and the following procedure was adopted: A 2-gram sample of the well ground and mixed plant was burned, dissolved as much as possible in sulphuric acid, and a little sulphurous acid added to dissolve any manganese peroxide that may have been formed. If the concentration of acid is kept within the proper limits this method leaves nothing to be desired.

### BARIUM, CHROMIUM, VANADIUM, AND MOLYBDENUM.

For this determination 20 grams of the ground plant were ashed, fused with 10 grams sodium carbonate and 0.25 gram sodium nitrate. The methods outlined by Hillebrand[1] were applied. Except when grasses (high in silica) and pine needles (high in aluminum) are to be analyzed it is necessary to evaporate the solution only to near dryness, for the normally trifling amount of silica and aluminum present will do no harm. It has been found helpful to titrate the dissolved and filtered melt nearly to the neutral point, using methyl orange as an indicator, prior to the precipitation of the mercurous salts. The results for barium and chromium were satisfactory and are believed to be reliable. The vanadium tests, however, were not so sharp cut. The color reaction with hydrogen peroxide in nitric-acid solution was used. No samples of plant ash contained enough to titrate with permanganate. It required 0.0002 gram $V_2O_5$ to give the characteristic vanadium test when added to 20 grams of the dry plant before incineration. The chromium and molybdenum tests were slightly more delicate. Spectroscopic tests for these elements were not used. Where vanadium, chromium, and molybdenum are reported as not found, there is less than 0.0002 gram of any one of those elements in 20 grams of the dry plant, or less than 0.001 per cent.

### STRONTIUM.

The determination of strontium in plant ash is not satisfactory. A large amount of calcium is always present, a fact which necessitates a large volume in which the precipitation is to be made. It seems probable that a considerable portion of the small amount of strontium present escapes precipitation in both the sulphate and oxalate separations. Further, some strontium nitrate is probably dissolved by the comparatively large amount of absolute ether-alcohol which must be used to dissolve the calcium nitrate and completely wash it from the strontium nitrate. An error in the other direction arises through the difficulty of washing the strontium nitrate free from calcium salts. A spectroscopic examination of the final strontium precipitate with the Bunsen burner as a source of heat always showed the characteristic strontium line, and the calcium lines were very faint or missing. The writers believe the accuracy of the strontium determination to be such that the differences in plant composition shown in the tables for this element are not significant.

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[1] Bul. 422, U. S. Geol. Survey, pp. 138 and 150 (1910).

### SULPHUR.

The sulphur determinations were made by two different methods, the Parr bomb method and the sodium-peroxide method. Both determinations yielded satisfactory results.

### CHLORINE.

The determinations of this element were made according to Bulletin 107 (Revised) of the Bureau of Chemistry. Satisfactory results were obtained.

### PHOSPHORIC ACID, CALCIUM, AND MAGNESIUM.

The phosphoric acid, calcium, and magnesium determinations were quite satisfactory, determinations by different individuals generally checking within 0.05 of 1 per cent.

### MOISTURE.

The loss in weight in an electric oven kept at 105° C. was taken to represent the moisture. In some cases constant weight was reached by drying from four to six hours, but generally the drying had to run much longer. Volatile materials other than water were certainly lost, as the strong continuous odor from the samples of pine needles and onions indicated. It was not practicable to dry the onions to constant weight, and the percentages are calculated on the air-dry basis. Throughout the work duplicate determinations were made until the analyst became very familiar with the procedures, and thereafter difficult determinations were made in duplicate and unusual results were always checked up, generally by another analyst.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 578
OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. ▼ February 9, 1918

# A STUDY OF HAYMAKING CREWS AND LABOR COSTS

By

**H. B. McCLURE, Agriculturist**

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 582

OFFICE OF THE SECRETARY
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief

Washington, D. C. ▼ January 7, 1918

# FARM MANAGEMENT AND FARM PROFITS ON IRRIGATED LAND IN THE PROVO AREA

## (UTAH LAKE VALLEY)

By

**L. G. CONNOR, Assistant Agriculturist**

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 583
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LOGAN WALLER PAGE, Director

Washington, D. C. ▼ March 7, 1918

# REPORT ON EXPERIMENTAL CONVICT ROAD CAMP FULTON COUNTY, GA.

By

H. S. FAIRBANK and R. H. EASTHAM, Highway Engineers,
and W. F. DRAPER, Passed Assistant Surgeon,
U. S. Public Health Service

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UNITED STATES DEPARTMENT OF AGRICULTURE

**BULLETIN No. 597**

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER April 9, 1918

# SOME BIOLOGICAL AND CONTROL STUDIES OF GASTROPHILUS HAEMORRHOIDALIS AND OTHER BOTS OF HORSES

By

**W. E. DOVE, Scientific Assistant**
**Insects Affecting Domestic Animals**

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WASHINGTON
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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 594
Contribution from the Bureau of Crop Estimates
L. M. ESTABROOK, Chief

Washington, D. C. February 21, 1918

# GEOGRAPHY OF WHEAT PRICES

## SUMMARY OF CONDITIONS AFFECTING FARM PRICES OF WHEAT IN DIFFERENT PARTS OF THE UNITED STATES

By

L. B. ZAPOLEON, Division of Crop Records

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

UNITED STATES DEPARTMENT OF AGRICULTURE

## BULLETIN No. 591

Contribution from the Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. PROFESSIONAL PAPER December 26, 1917

# MANUFACTURING TESTS OF THE OFFICIAL COTTON STANDARDS FOR GRADE

By

**WILLIAM S. DEAN, Assistant in Cotton Testing**
**and FRED TAYLOR, Cotton Technologist**

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NOTE.—This bulletin should be of interest to cotton producers, manufacturers, and dealers

WASHINGTON
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1917

UNITED STATES DEPARTMENT OF AGRICULTURE

## BULLETIN No. 590

Contribution from the Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. ▼ February 27, 1918

# A SYSTEM OF ACCOUNTING FOR FRUIT SHIPPING ORGANIZATIONS

By

**G. A. NAHSTOLL and JOHN R. HUMPHREY, Investigators in Market Business Practice**

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 588

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. ▼ November 15, 1917

# INCREASED CATTLE PRODUCTION ON SOUTHWESTERN RANGES

By

**JAMES T. JARDINE, Inspector of Grazing, and**
**L. C. HURTT, Grazing Examiner**

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 587
Joint Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief,
and the Bureau of Markets, CHARLES J. BRAND, Chief

Washington, D. C. ▼ September 8, 1917

# THE HANDLING AND STORAGE OF APPLES IN THE PACIFIC NORTHWEST

By

**H. J. RAMSEY**, Pomologist in Charge, Fruit Handling and Storage Investigations; **A. W. McKAY**, formerly Pomologist; **E. L. MARKELL** and **H. S. BIRD**, formerly Scientific Assistants, Office of Horticultural and Pomological Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE
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Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER February 28, 1918

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 592
Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER November 5, 1917

# COURSES IN SECONDARY AGRICULTURE FOR SOUTHERN SCHOOLS

## (THIRD AND FOURTH YEARS)

By

**H. P. BARROWS, Specialist in Agricultural Education**

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 595

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ October 11, 1917

# WINTER WHEAT IN THE GREAT PLAINS AREA

## RELATION OF CULTURAL METHODS TO PRODUCTION

By

E. C. CHILCOTT, Agriculturist in Charge, JOHN S. COLE,
Agriculturist, and J. B. KUSKA, Assistant,
Office of Dry-Land Agriculture

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1917

All of the members of the scientific staff of the Office of Dry-Land Agriculture have contributed more or less to this bulletin by having charge of field investigations and by assisting in the preparation of data for records or for publication. The scientific staff as at present constituted consists of the following members named in the order of length of service: E. F. Chilcott, Woodward, Okla.; O. J. Grace, Akron, Colo.; J. S. Cole, Washington, D. C.; J. M. Stephens, Moccasin, Mont.; A. L. Hallsted, Hays, Kans.; O. R. Mathews, Belle Fourche, S. Dak.; J. C. Thysell, Dickinson, N. Dak.; M. Pfaender, Mandan, N. Dak.; W. M. Osborn, Lawton, Okla.; W. D. Griggs, Dalhart, Tex.; J. E. Mundell, Big Spring, Tex.; F. L. Kelso, Ardmore, S. Dak.; W. A. Peterson, Mandan, N. Dak.; J. T. Sarvis, Mandan, N. Dak.; G. W. Morgan, Havre, Mont.; H. G. Smith, Tucumcari, N. Mex.; L. N. Jensen, Amarillo, Tex.; R. S. Towle, Edgeley, N. Dak.; A. J. Ogaard, Hettinger, N. Dak.; C. B. Brown, Garden City, Kans.; L. D. Willey, Sheridan, Wyo.; J. B. Kuska, Colby, Kans.; A. E. Seamans, Huntley, Mont.; L. L. Zook, North Platte, Nebr.; C. H. Ružicka, Williston, N. Dak.; A. W. Schulz, Mandan, N. Dak.; R. W. Wilson, Mandan, N. Dak.; W. E. Lyness, Archer, Wyo.; F. A. Wagner, Big Spring, Tex.; H. J. Clemmer, Woodward, Okla.; F. E. Cobb, Mandan, N. Dak.; A. Osenbrug, Scottsbluff, Nebr.; J. F. Brandon, Akron, Colo.; and T. P. Baird, Moccasin, Mont.

The following-named men have held positions on the scientific staff of the Office of Dry-Land Agriculture during the past nine years, but have resigned or have been transferred to other offices of the Department of Agriculture: Sylvester Balz, F. L. Kennard, J. E. Payne, L. E. Hazen, C. A. Jensen, H. R. Reed, W. O. Whitcomb, C. H. Plath, F. Knorr, R. W. Edwards, H. C. McKinstry, C. A. Burmeister, J. G. Lill, W. W. Burr, and J. H. Jacobson.

The data here reported from the stations in Kansas, Nebraska, North Dakota, and Montana have been obtained in cooperation with the agricultural experiment stations of the respective States. In South Dakota, Colorado, Texas, Oklahoma, and New Mexico the stations are operated by the United States Department of Agriculture.

Field, office, and laboratory facilities, teams, and implements have been provided by the Office of Western Irrigation Agriculture at Huntley, Mont., Belle Fourche, S. Dak., and Mitchell, Nebr., and by the Office of Cereal Investigations at Amarillo, Tex., and Archer, Wyo. The Biophysical Laboratory has cooperated in obtaining the meteorological data reported.

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